MISSOURI
DEPARTMENT OF
NATURAL RESOURCES
Missouri Geological Survey

US Army Corps
of Engineers

MISSOURI
WATER RESOURCES PLAN

Agricultural Needs
Technical Workgroup

May 16, 2018, 1:00 p.m. to 4:00 p.m.

Missouri Water
Resources Plan

Welcome!

Jennifer Hoggatt

Director

Water Resources Center

Agenda Overview

- Introduction and Meeting Format
- Missouri Department of Natural Resources Project Vision
- Water Supply Analysis and Results (HUC4)
- Water Quality Analysis and Results
- Agricultural Demands Update
- IATF Report Out
- Next Steps
- Public Comments

Missouri Water Resources Plan Vision

- Statutory Responsibility (640.415 RSMo):

  "The department shall develop, maintain and periodically update a state water plan for a long-range, comprehensive statewide program for the use of surface water and groundwater resources of the state, including existing and future need for drinking water supplies, agriculture, industry, recreation, environmental protection and related needs."

Project Vision (MoDNR)

The Missouri Water Resources Plan is a long range, comprehensive strategy to:

- Provide an understanding of water resource needs
- Ensure the quantity of water resources meets future water demands
  - Identify future water supply shortfalls
  - Explore options to address water needs

Missouri Water Resources Plan Update: **Goals**

1. Gather public and stakeholder input to help identify needs and priority areas of water resource development.
2. Establish key stakeholder advisory and technical groups to help guide water plan development.
3. Develop an updated evaluation of current groundwater and surface water availability and develop projected water supply needs.
4. Produce an in-depth analysis of current and future consumptive, non-consumptive and agricultural water needs, and identify gaps in water availability based on water demand projections.
5. Identify water and wastewater infrastructure needs, and evaluate funding and financing opportunities.
6. Recognize water quality and assess how this affects water supply uses.
7. Understand areas where developing new and more sustainable water sources, better infrastructure, and more integrated water supplies can help to sustain water delivery.
8. To better understand regionally where future water gaps may exist, as studies have revealed in parts of southwest and northern Missouri.

Surface Water Supply Overview

- Surface water supply analysis goals
- HUC4 surface water analyses
  - Approach
  - Average annual water budget summary
  - Demands by water use sector
  - Monthly comparisons of supply and demand
  - Flow-duration curves
  - Reservoirs
- HUC8 demand comparisons
- Next steps

Surface Water Supply Analysis Goals

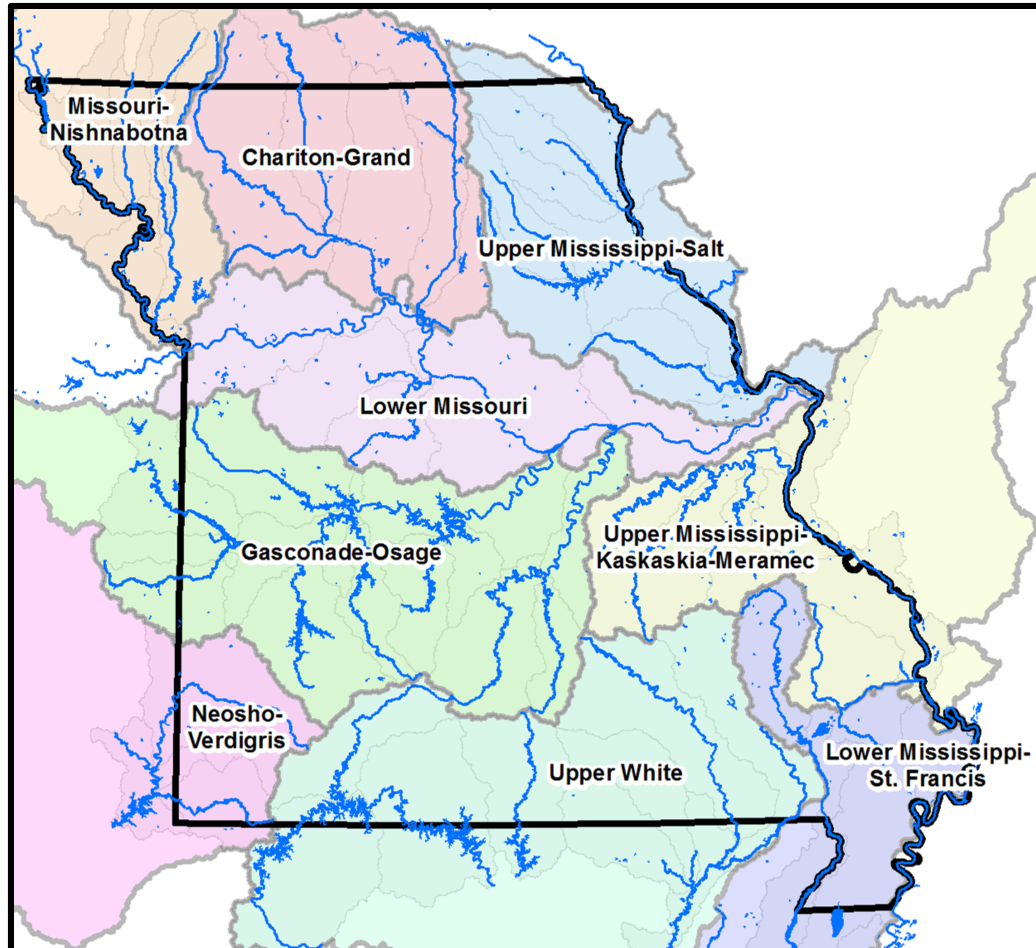
- At a HUC4 level, evaluate and summarize:
  - Surface water availability (streamflow)
  - Demands, both consumptive and non-consumptive
  - Gaps in available supply compared to demands
- Evaluate wet, dry, and average years on an annual and monthly basis
- Use results to support the infrastructure task
- Establish baseline for scenario planning

How Water Budgets are Used to Support Statewide Planning

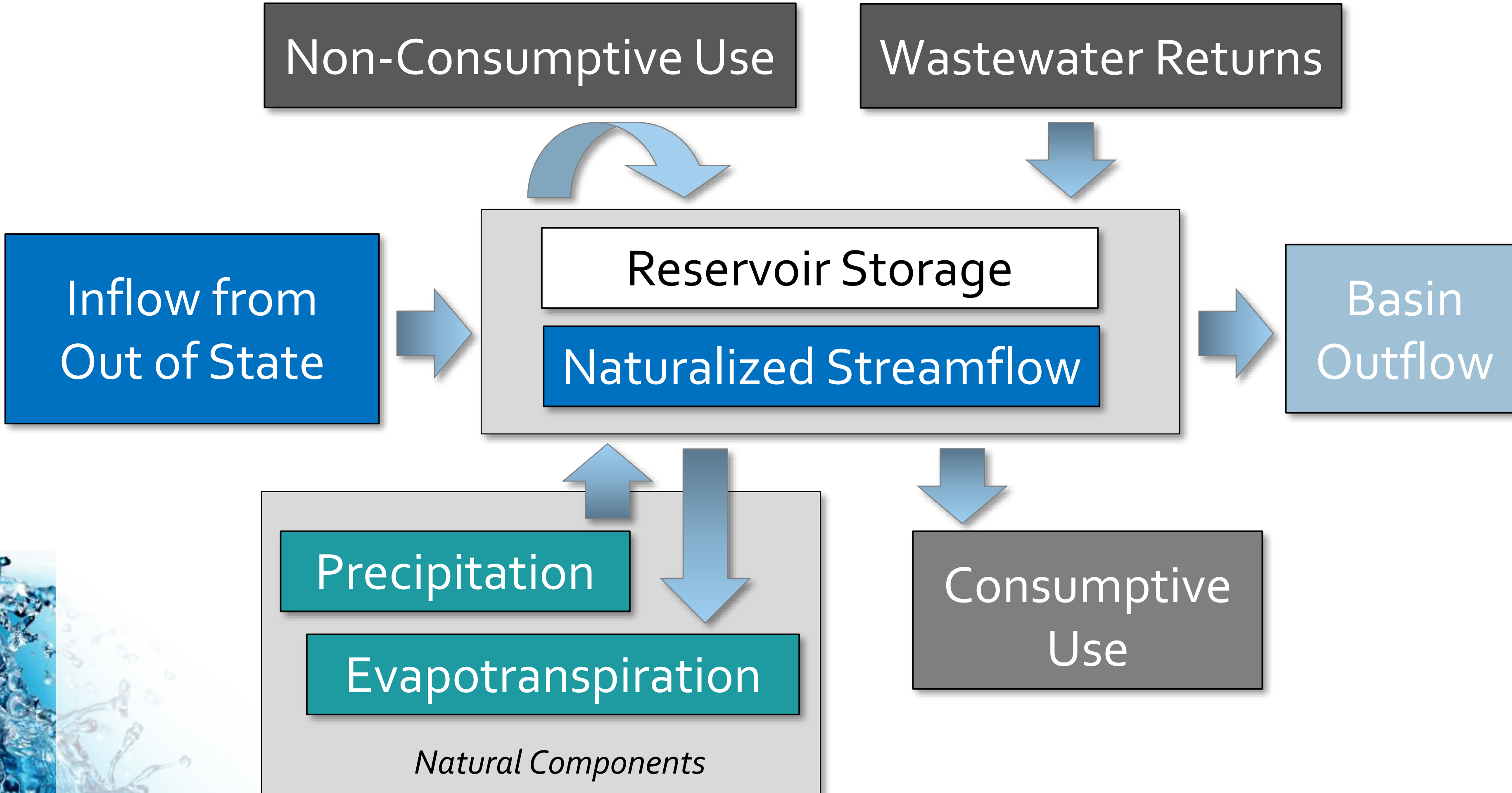
- Provide an understanding of the availability, movement, and use of water within each basin.
- Provide a concise means of comparing basins with each other in terms of water availability and water consumption.
- Compare the natural versus manmade components of the hydrologic cycle.
- Identify where water management decisions will result in the most impact by understanding which basins may have water surpluses and which may have potential shortfalls with respect to satisfying all consumptive and non-consumptive uses.
- Provide a basis to assess sustainability of water resources.

Scale of Assessment

- Nine major HUC4 watersheds in Missouri analyzed
- Average area in Missouri of 7,700 square miles
- Analysis looks at each HUC4 as a whole – results are at the outlet of each basin

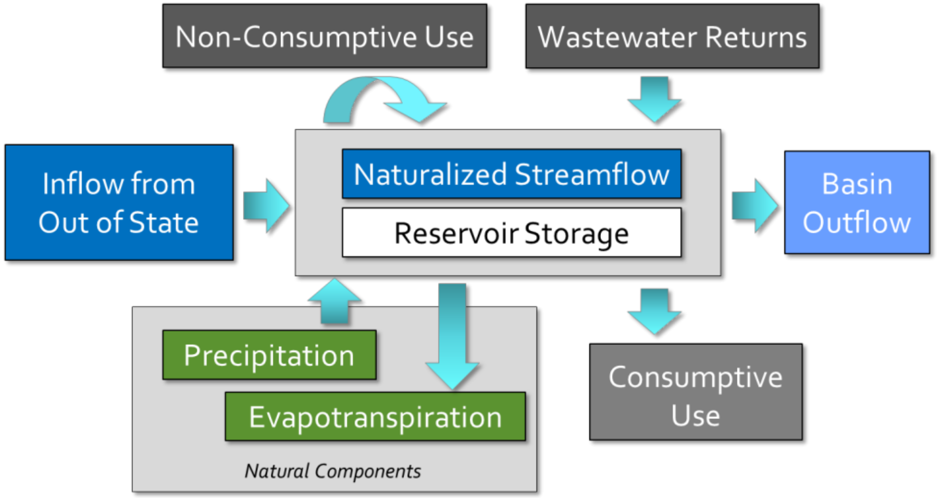


Surface Water Budget



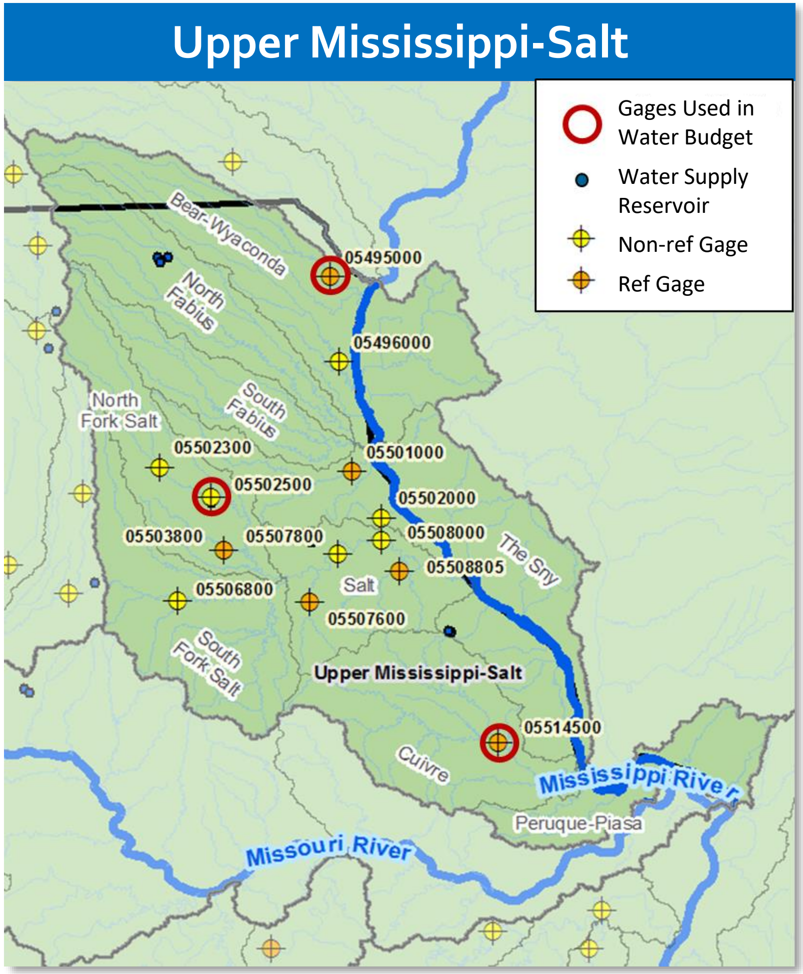
Definitions

- **Naturalized streamflow** is streamflow that has been adjusted to remove impacts associated with withdrawals and discharges
- **Non-consumptive use** includes:
  - Thermoelectric
  - Aquaculture and wetlands
- **Consumptive use** includes:
  - Public supply
  - Agriculture
  - Non-residential self-supply
  - Residential self-supply



How is Naturalized Streamflow Quantified?

- Representative USGS streamflow gages are selected
- Monthly flow records are unimpaired
- Composite flow developed based on drainage area to each selected gage, then scaled for entire basin
- Streamflow represents available flow at the outlet of each basin



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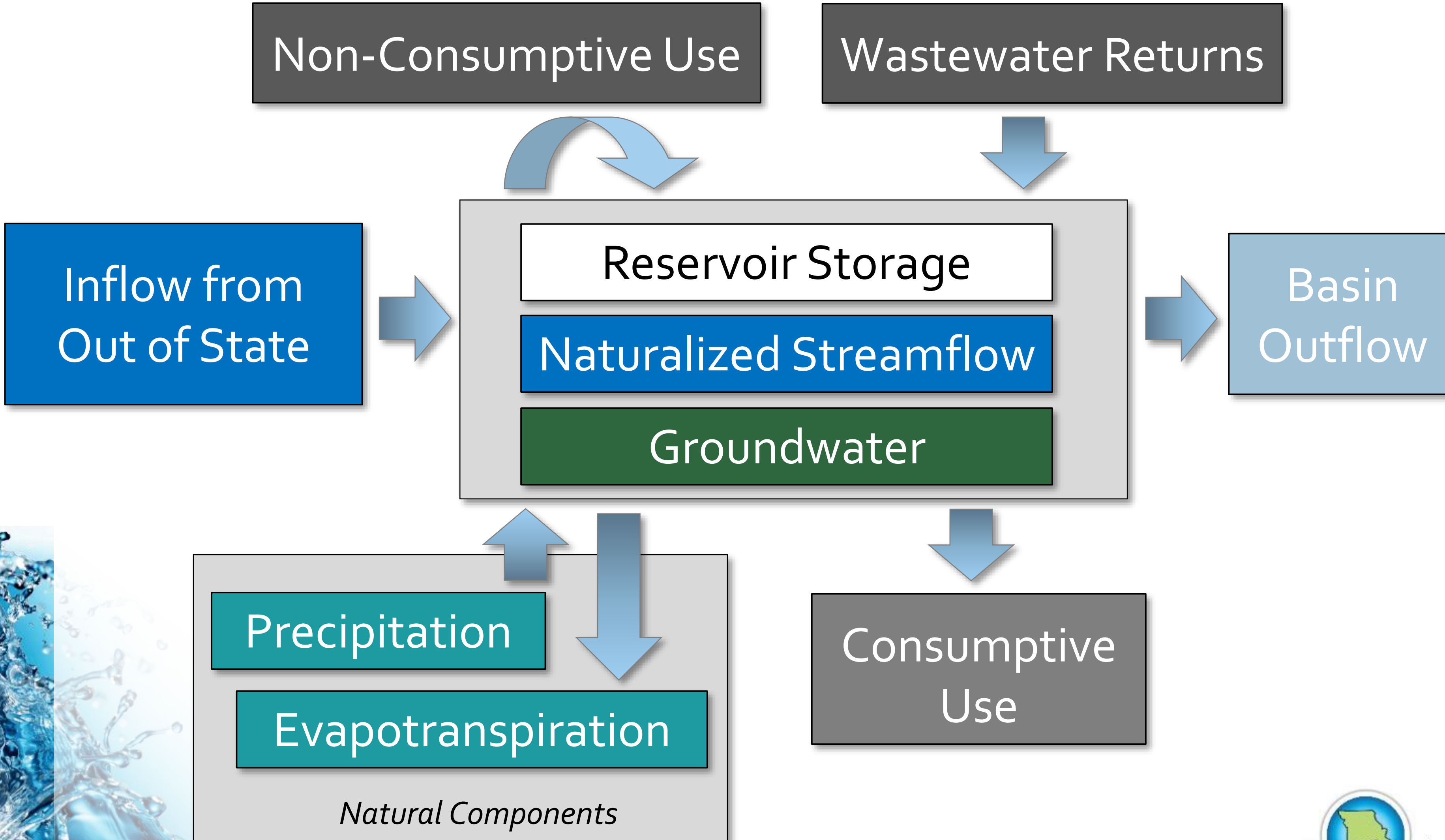
Total Water Budget



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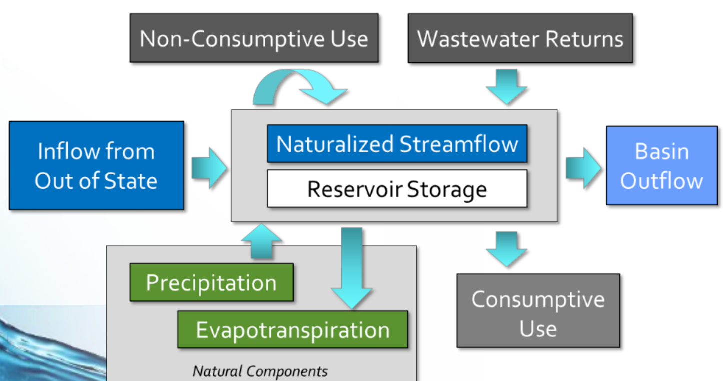
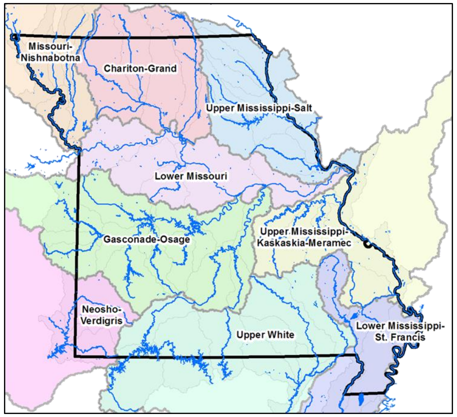
HUC4 Current Surface Water Budget (mgd)

		Values in Million Gallons per Day, based on Average Annual Conditions										
		Natural Components		Streamflow				Withdrawals and Returns				Outflow
HUC4	Name	Precipitation	Evapo-transpiration	Streamflow (from Out of State)	Streamflow (from an in state HUC4)	Streamflow (generated in HUC4)	Total Streamflow	Non-Consumptive Withdrawals	Non-Consumptive Returns	Consumptive Withdrawals	Wastewater Returns	Basin Outflow
711	Upper Mississippi-Salt	14,828	8,756	77,600	0	4,436	82,036	464	461	33	33	82,033
714	Upper Mississippi-Kaskaskia-Meramec	15,095	9,112	149,485	0	4,341	153,827	986	981	108	226	153,939
802	Lower Mississippi-St. Francis	10,869	5,761	155,286	0	1,751	157,037	3	4	14	13	157,037
1024	Missouri-Nishnabotna	6,343	3,945	32,073	0	1,760	33,832	913	928	97	21	33,772
1028	Chariton-Grand	15,242	9,020	1,304	0	4,095	5,399	770	765	30	10	5,374
1029	Gasconade-Osage	30,262	18,486	2,826	0	9,393	12,219	176	175	30	27	12,215
1030	Lower Missouri	20,540	12,055	37,735	20,540	6,074	64,348	2,182	2,154	223	185	64,282
1101	Upper White	23,634	14,195	1,869	0	9,129	10,998	110	112	42	44	11,002
1107	Neosho-Verdigris	6,369	3,881	0	0	1,851	1,851	5	6	21	24	1,854





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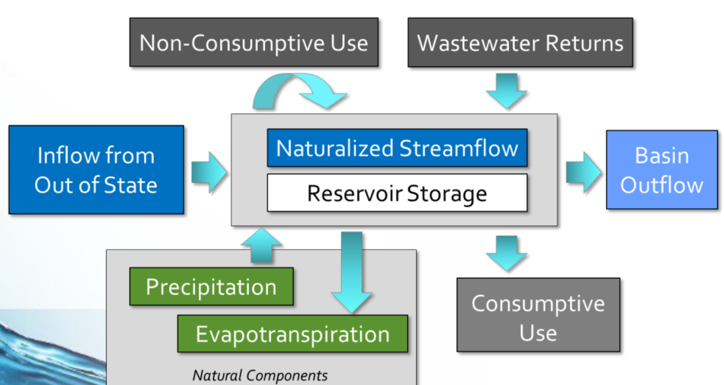
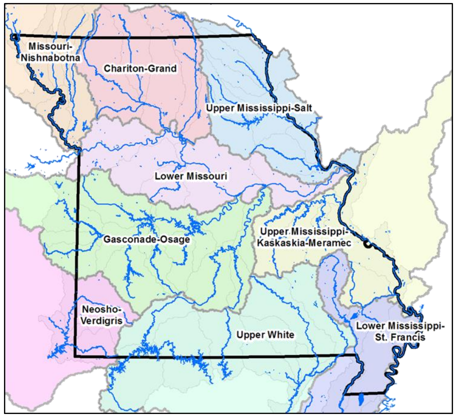
HUC4 Current Surface Water Budget (in/yr)

		Values in Inches per Year, based on Average Annual Conditions										
		Natural Components		Streamflow				Withdrawals and Returns				Outflow
HUC4	Name	Precipitation	Evapo-transpiration	Streamflow (from Out of State)	Streamflow (from an in state HUC4)	Streamflow (generated in HUC4)	Total Streamflow	Non-Consumptive Withdrawals	Non-Consumptive Returns	Consumptive Withdrawals	Wastewater Returns	Basin Outflow
711	Upper Mississippi-Salt	40.1	23.7	210.1	0.0	12.0	222.1	1.3	1.2	0.1	0.1	222.1
714	Upper Mississippi-Kaskaskia-Meramec	45.4	27.4	449.7	0.0	13.1	462.8	3.0	3.0	0.3	0.7	463.1
802	Lower Mississippi-St. Francis	48.4	25.7	691.9	0.0	7.8	699.7	0.0	0.0	0.1	0.1	699.7
1024	Missouri-Nishnabotna	36.2	22.5	183.1	0.0	10.0	193.1	5.2	5.3	0.6	0.1	192.8
1028	Chariton-Grand	38.6	22.8	3.3	0.0	10.4	13.7	1.9	1.9	0.1	0.0	13.6
1029	Gasconade-Osage	44.5	27.2	4.2	0.0	13.8	18.0	0.3	0.3	0.0	0.0	18.0
1030	Lower Missouri	42.4	24.9	77.9	42.4	12.5	132.8	4.5	4.4	0.5	0.4	132.7
1101	Upper White	46.8	28.1	3.7	0.0	18.1	21.8	0.2	0.2	0.1	0.1	21.8
1107	Neosho-Verdigris	46.0	28.1	0.0	0.0	13.4	13.4	0.0	0.0	0.2	0.2	13.4





Comparison of Surface Water Supply and Demand

HUC4	Name	Total Streamflow (mgd)	Total Withdrawals as a Percent of Total Streamflow	
			Current	2060
711	Upper Mississippi-Salt	82,036	0.6%	0.1%
714	Upper Mississippi-Kaskaskia-Meramec	153,827	0.7%	0.7%
802	Lower Mississippi-St. Francis	157,037	0.0%	0.0%
1024	Missouri-Nishnabotna	33,832	3.0%	3.5%
1028	Chariton-Grand	5,399	14.8%	17.4%
1029	Gasconade-Osage	12,219	1.7%	2.0%
1030	Lower Missouri	64,348	3.7%	2.9%
1101	Upper White	10,998	1.4%	1.6%
1107	Neosho-Verdigris	1,851	1.4%	1.8%

Comparison of Surface Water Supply and Demand

			Non-Consumptive Withdrawals as a Percent of Total Streamflow		Consumptive Withdrawals as a Percent of Total Streamflow	
HUC4	Name	Total Streamflow (mgd)	Current	2060	Current	2060
711	Upper Mississippi-Salt	82,036	0.6%	0.0%	0.0%	0.1%
714	Upper Mississippi-Kaskaskia-Meramec	153,827	0.6%	0.6%	0.1%	0.1%
802	Lower Mississippi-St. Francis	157,037	0.0%	0.0%	0.0%	0.0%
1024	Missouri-Nishnabotna	33,832	2.7%	3.2%	0.3%	0.4%
1028	Chariton-Grand	5,399	14.3%	16.7%	0.5%	0.7%
1029	Gasconade-Osage	12,219	1.4%	1.6%	0.2%	0.3%
1030	Lower Missouri	64,348	3.4%	2.5%	0.3%	0.4%
1101	Upper White	10,998	1.0%	1.0%	0.4%	0.6%
1107	Neosho-Verdigris	1,851	0.3%	0.3%	1.1%	1.6%

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Comparison of Surface Water Supply and Demand

			Non-Consumptive Withdrawals as a Percent of Total Streamflow		Consumptive Withdrawals as a Percent of Total Streamflow	
HUC4	Name	Total Streamflow (mgd)	Current	2060	Current	2060
711	Upper Mississippi-Salt	82,036	0.6%	0.0%	0.0%	0.1%
714	Upper Mississippi-Kaskaskia-Meramec	153,827	0.6%	0.6%	0.1%	0.1%
802	Lower Mississippi-St. Francis	157,037	0.0%	0.0%	0.0%	0.0%
1024	Missouri-Nishnabotna	33,832	2.7%	3.2%	0.3%	0.4%
1028	Chariton-Grand	5,399	14.3%	16.7%	0.5%	0.7%
1029	Gasconade-Osage	12,219	1.4%	1.6%	0.2%	0.3%
1030	Lower Missouri	64,348	3.4%	2.5%	0.3%	0.4%
1101	Upper White	10,998	1.0%	1.0%	0.4%	0.6%
1107	Neosho-Verdigris	1,851	0.3%	0.3%	1.1%	1.6%

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Comparison of Surface Water Supply and Demand

HUC4	Name	Streamflow Generated in HUC4 (mgd)	Consumptive Withdrawals as a Percent of Streamflow Generated in HUC4	
			Current	2060
711	Upper Mississippi-Salt	4,436	0.8%	1.0%
714	Upper Mississippi-Kaskaskia-Meramec	4,341	2.5%	2.4%
802	Lower Mississippi-St. Francis	1,751	0.8%	1.0%
1024	Missouri-Nishnabotna	1,760	5.5%	7.1%
1028	Chariton-Grand	4,095	0.7%	0.9%
1029	Gasconade-Osage	9,393	0.3%	0.4%
1030	Lower Missouri	6,074	3.7%	4.6%
1101	Upper White	9,129	0.5%	0.7%
1107	Neosho-Verdigris	1,851	1.1%	1.6%

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What Do the HUC4 Surface Water Budgets Tell Us?

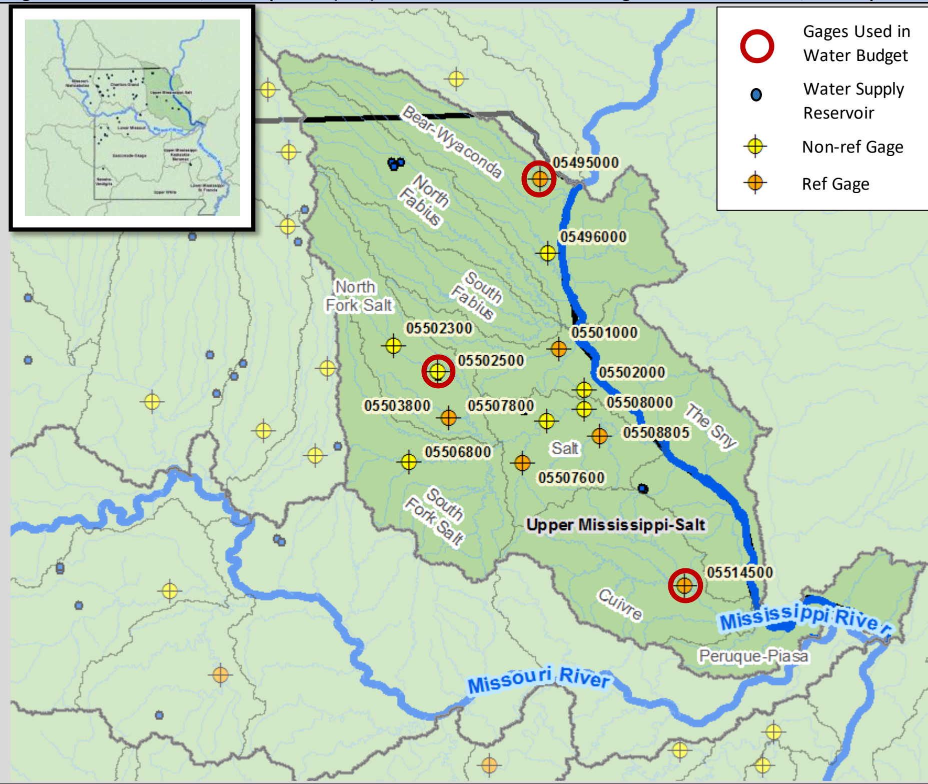
On an ***average annual*** basis:

- Flows from out of state are dominant in 5 of 9 HUC4 basins
- Natural components are also dominant (precipitation and ET)
- Consumptive withdrawals are typically:
  - < 1% of total streamflow
  - 1%–5% of streamflow generated in the basins
- Supply far exceeds demand at HUC4 scale (no gaps)

HUC4 Basin Summaries

Upper Mississippi-Salt Basin Summary

Basin Name:	Upper Mississippi-Salt	HUC4 Number:	711
Drainage Area within MO:	7,764 sq miles (77%)	Contributing Area outside MO:	2,313 sq miles (23%)



Annual Surface Water Budget

The annual water budget reflects average hydrologic conditions and current demands.
All values are in million gallons per day (mgd), unless noted.

Non-Consumptive Use

Withdrawals	464
Returns	461

Wastewater Returns

32.7

Inflows

Streamflow (from Out-of-State)	77,600
Precipitation (In-State)	14,828

Naturalized Streamflow	4,436	
Water Supply Reservoir Storage	2,611	million gallons

Surface Water Outflow

82,033

Consumptive Use & ET

Evapotranspiration	8,756
Consumptive Withdrawals	33.3

MISSOURI WATER RESOURCES PLAN

HUC4 Basin Summaries

Upper Mississippi-Salt Basin Summary

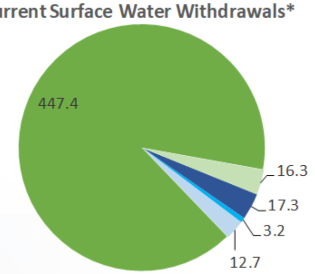
Annual Surface Water Budget Summary

	ac-ft/yr	in/yr	mgd
Precipitation (In-State)	16,622,428	40.14	14,828
Evapotranspiration	9,815,373	23.70	8,756
Streamflow (from Out-of-State)	86,988,735	210.08	77,600
Streamflow (from other In-State HUC4 basin)	0	0.00	0
Streamflow originating in HUC4	4,973,043	12.01	4,436
Total Streamflow	91,961,779	222.09	82,036
Non-Consumptive Surface Water Withdrawals	519,851	1.26	464
Consumptive Surface Water Withdrawals	37,312	0.09	33.3
Total Surface Water Withdrawals	557,163	1.35	497

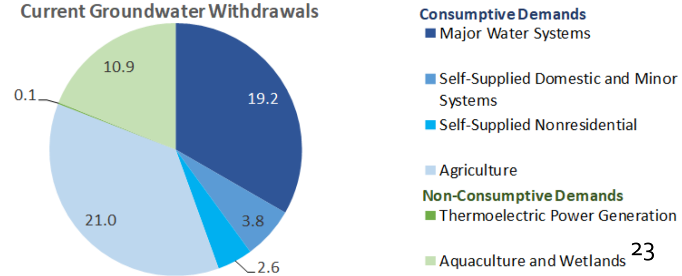
Summary Water Demands by Sector

	Current Demands			2060 Demands
Surface Water Withdrawals By Sector	**ac-ft/yr**	**in/yr**	**mgd**	**mgd**
Major Water Systems	19,427	0.05	17.3	22.9
Self-Supplied Nonresidential	3,618	0.01	3.2	2.1
Agriculture	14,267	0.03	12.7	17.2
Total Consumptive	**37,312**	**0.09**	**33.3**	**42.2**
Thermoelectric Power Generation[1]	501,537	1.21	447.4	0.0
Aquaculture and Wetlands	18,313	0.04	16.3	16.3
Total Non-consumptive	**519,851**	**1.26**	**463.7**	**16.3**
Groundwater Withdrawals By Sector[2]	**ac-ft/yr**	**in/yr**	**mgd**	**mgd**
Major Water Systems	21,510	0.05	19.2	29.4
Self-Supplied Domestic and Minor Systems	4,294	0.01	3.8	3.7
Self-Supplied Nonresidential	2,920	0.01	2.6	2.9
Agriculture	23,524	0.06	21.0	25.4
Total Consumptive	**52,247**	**0.13**	**46.6**	**61.5**
Thermoelectric Power Generation	114	0.00	0.1	0.2
Aquaculture and Wetlands	12,220	0.03	10.9	10.9
Total Non-consumptive	**12,334**	**0.03**	**11.0**	**11.1**

Current Surface Water Withdrawals*



Current Groundwater Withdrawals



*Surface Water Demands do not include Self-Supplied Domestic sector
**Chart data labels represent demands in mgd.

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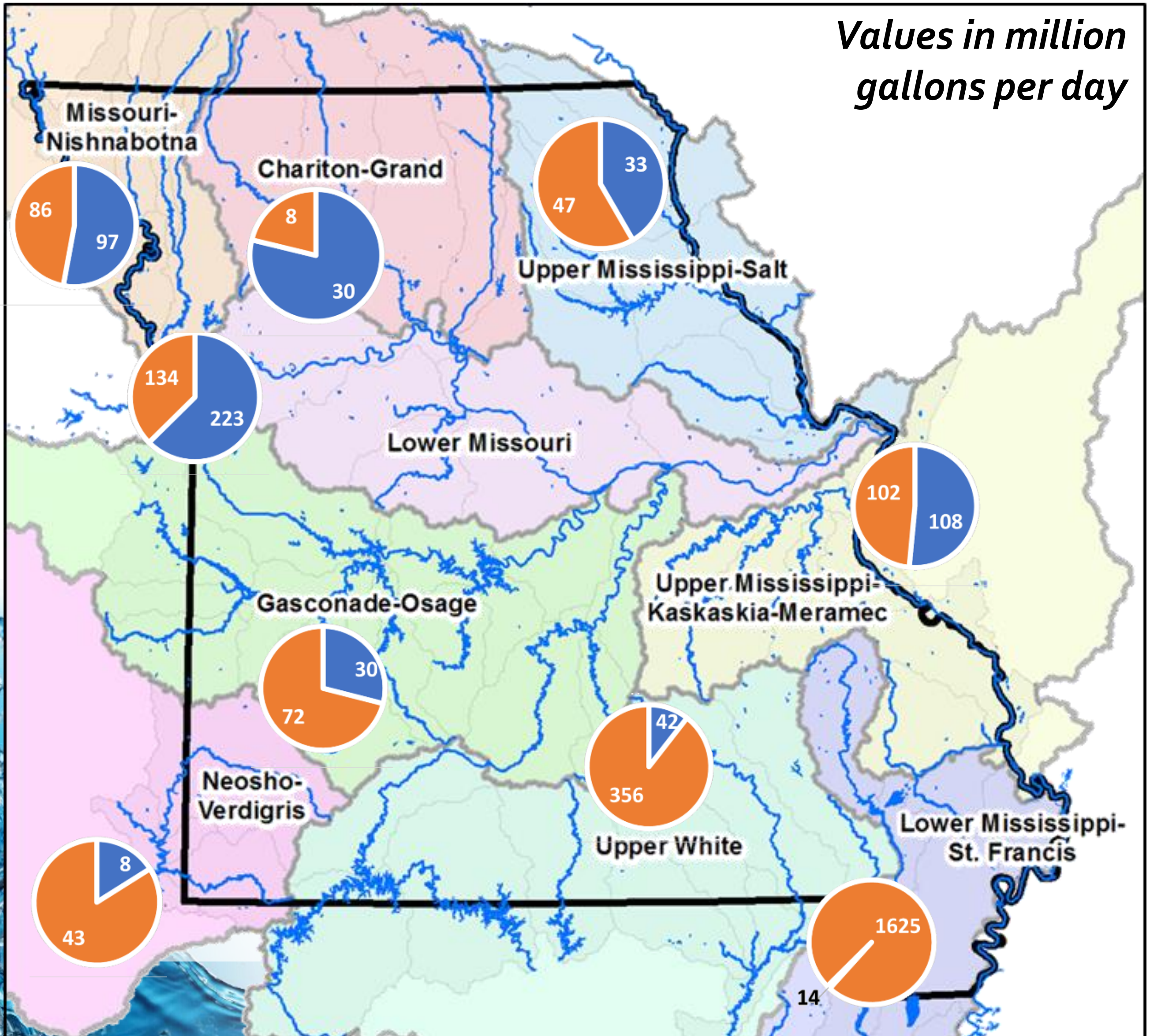
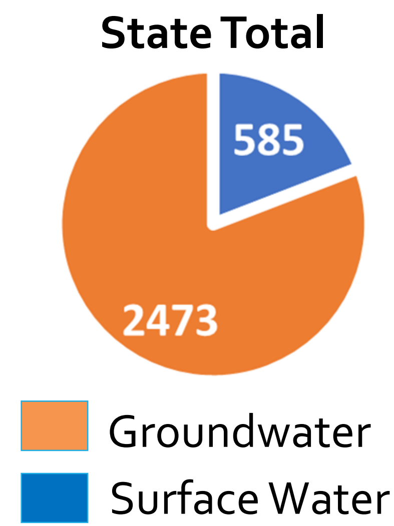
Current Consumptive Water Demands (mgd) by Source





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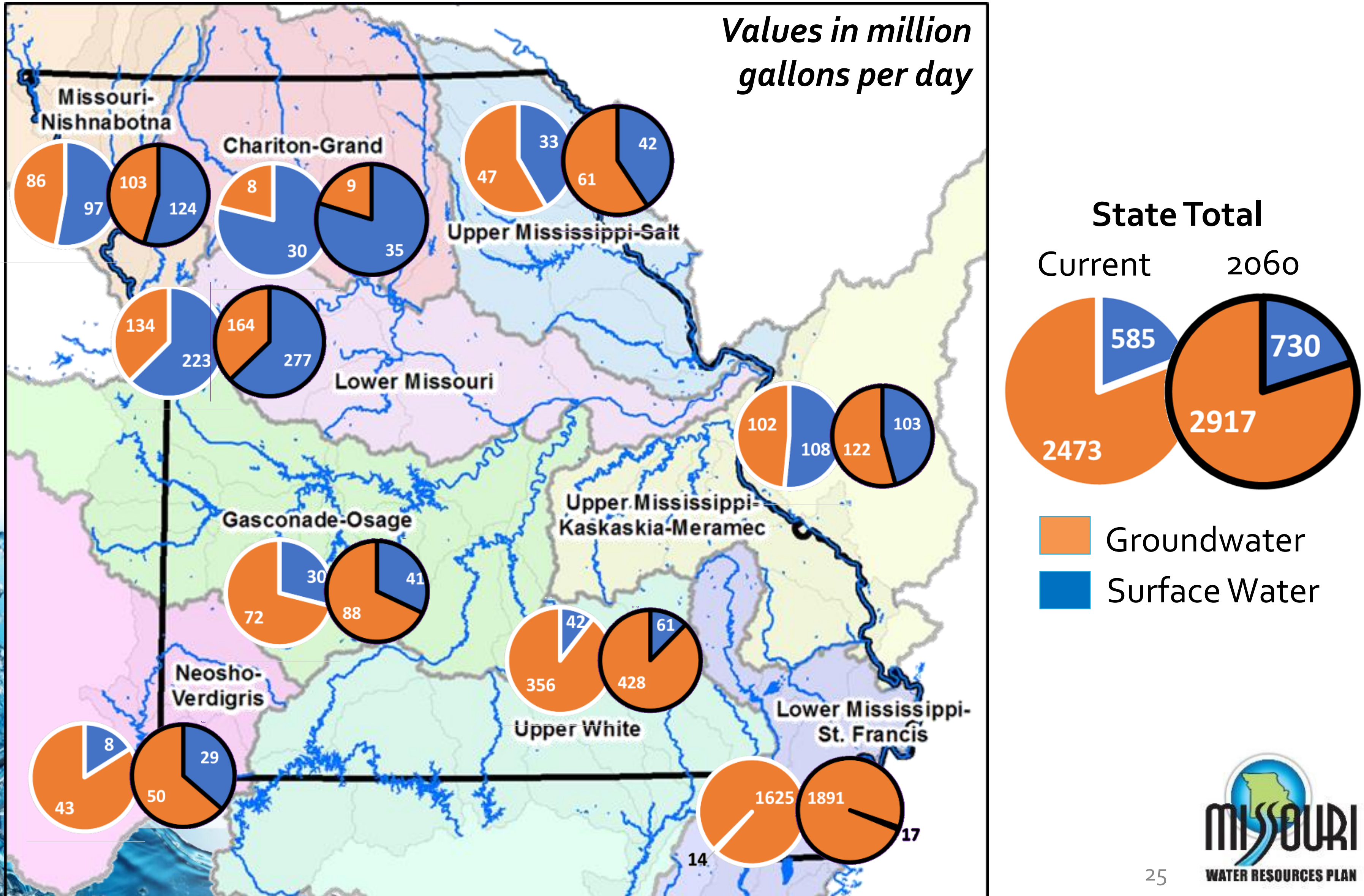
Current and 2060 Consumptive Water Demands (mgd) by Source



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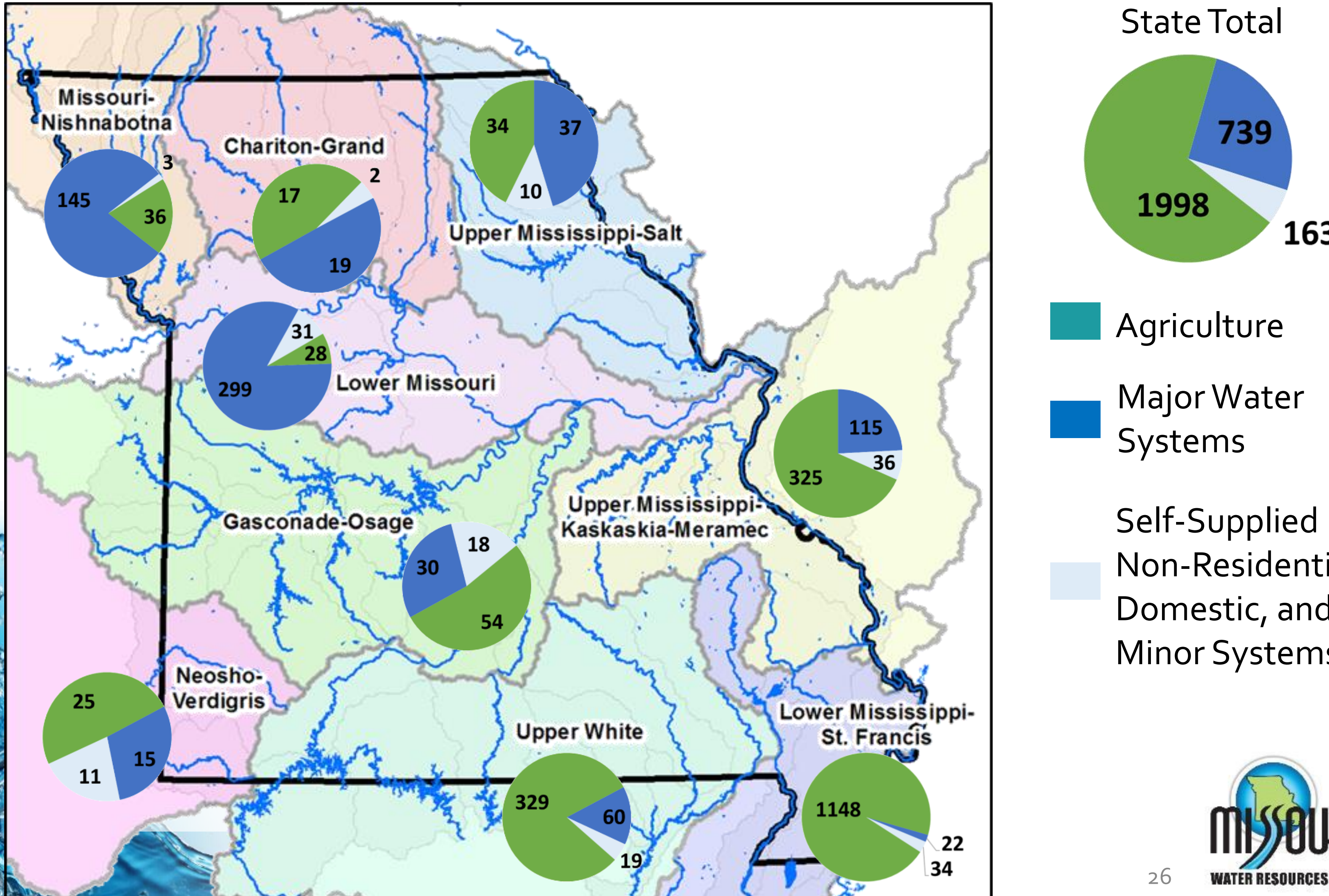
Current Total Consumptive Water Demands (mgd) by Sector



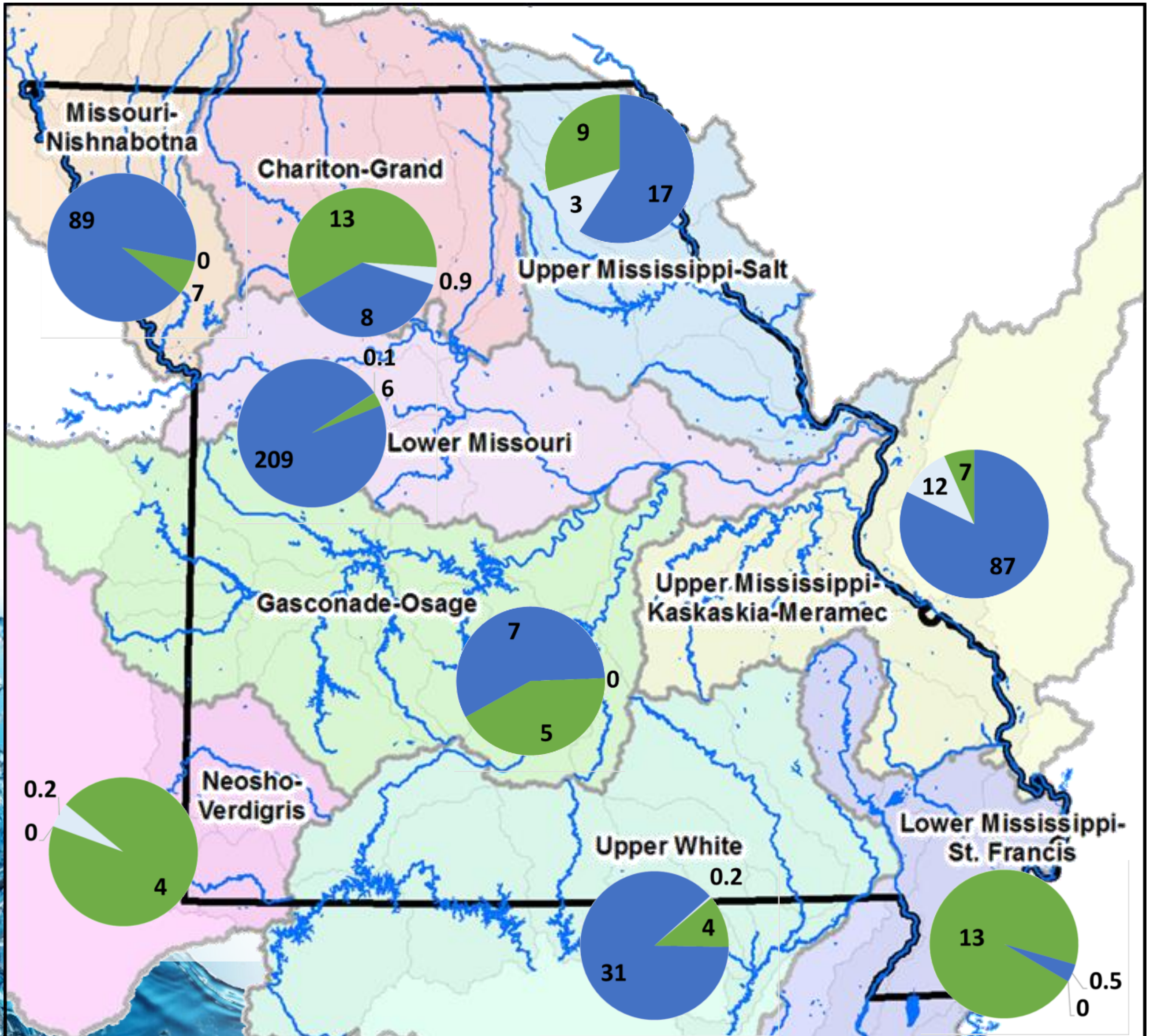
Agriculture

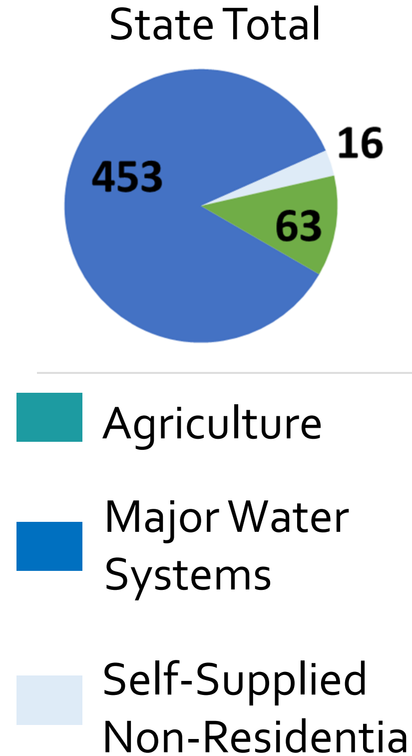
Major Water Systems

Self-Supplied Non-Residential, Domestic, and Minor Systems

MISSOURI WATER RESOURCES PLAN

Current Consumptive Surface Water Demands (mgd) by Sector





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What do the Demands by Sector Tell Us?

- Statewide, the majority of demands are groundwater
  - Groundwater demands are highest in 6 of 9 basins
  - Northern Missouri is more reliant on surface water
  - Nearly 82% of statewide consumptive demands are groundwater
  - This trend continues into the future
- Statewide, public supply is a dominant surface water demand
  - Public supply is the majority of all consumptive demands in 6 of 9 basins
  - Agriculture is also a major surface water demand, comprising the majority of demands in the remaining 3 basins

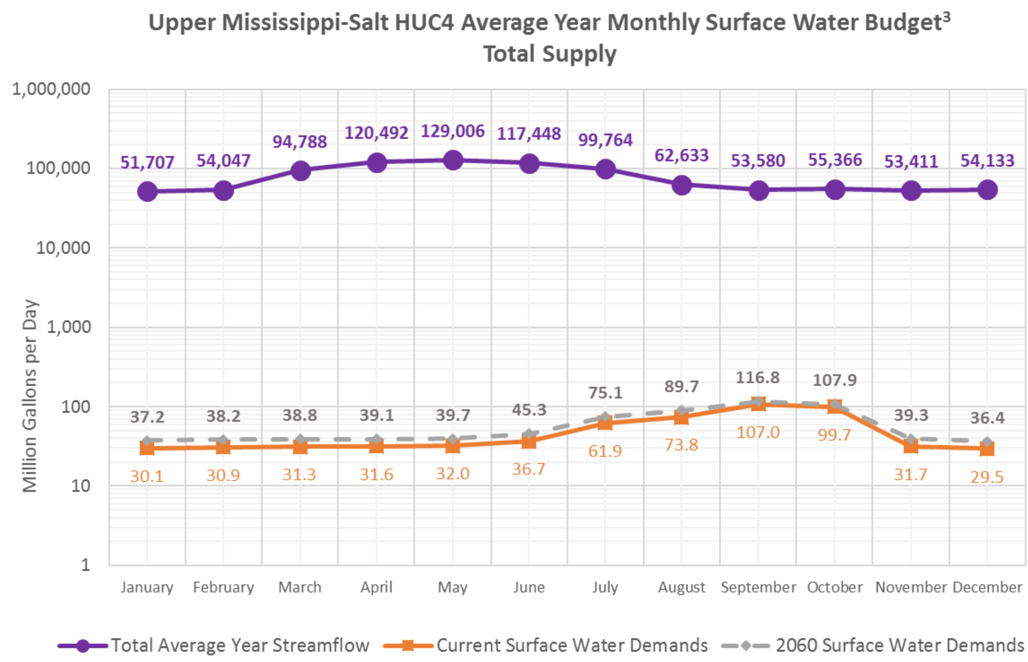
MISSOURI WATER RESOURCES PLAN

Monthly Comparisons of Availability and Demand

- Current and future monthly demands are compared to average annual and minimum year total streamflow
  - Minimum year is specific to the gage(s) used, and may vary for each HUC4
- Total streamflow includes:
  - Streamflow originating within the Missouri portion of the HUC4
  - Streamflow originating outside of the in-state portion of HUC4
    - ✓ Major rivers (Missouri and Mississippi)
    - ✓ Other flow entering from out-of-state portion of HUC4

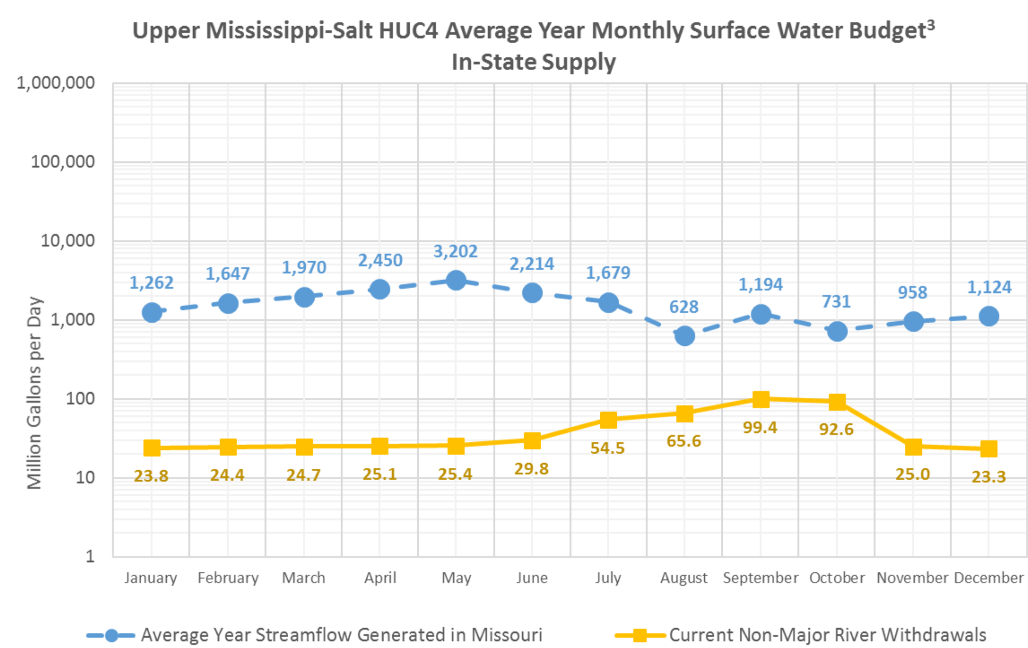
Monthly Comparisons of Supply and Demand

Total Supply Average Year



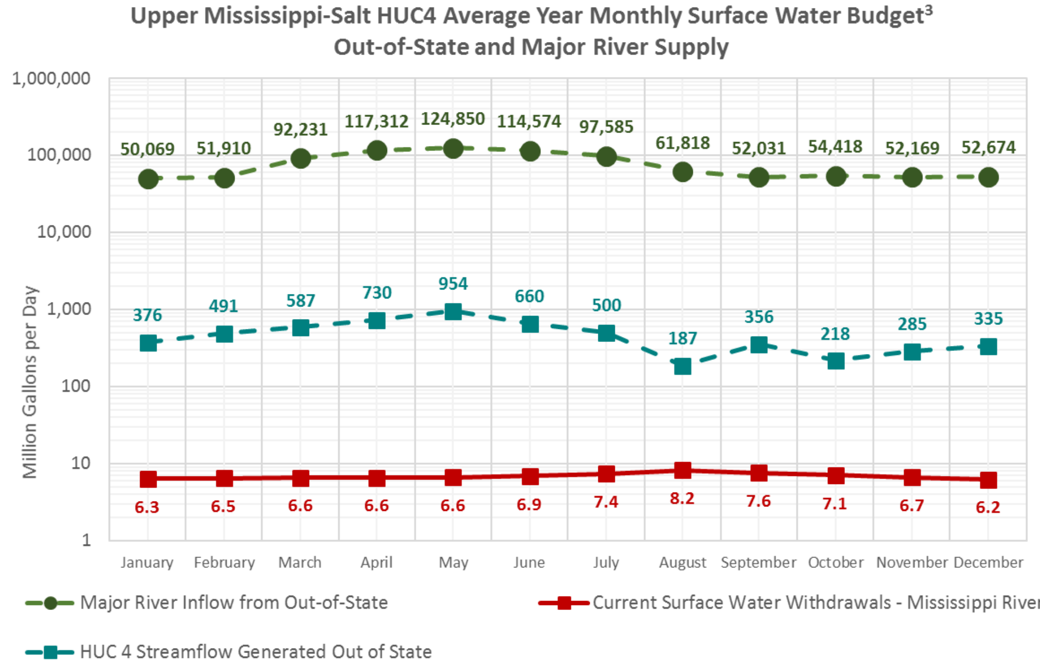
Upper Mississippi-Salt

In-State Supply Average Year



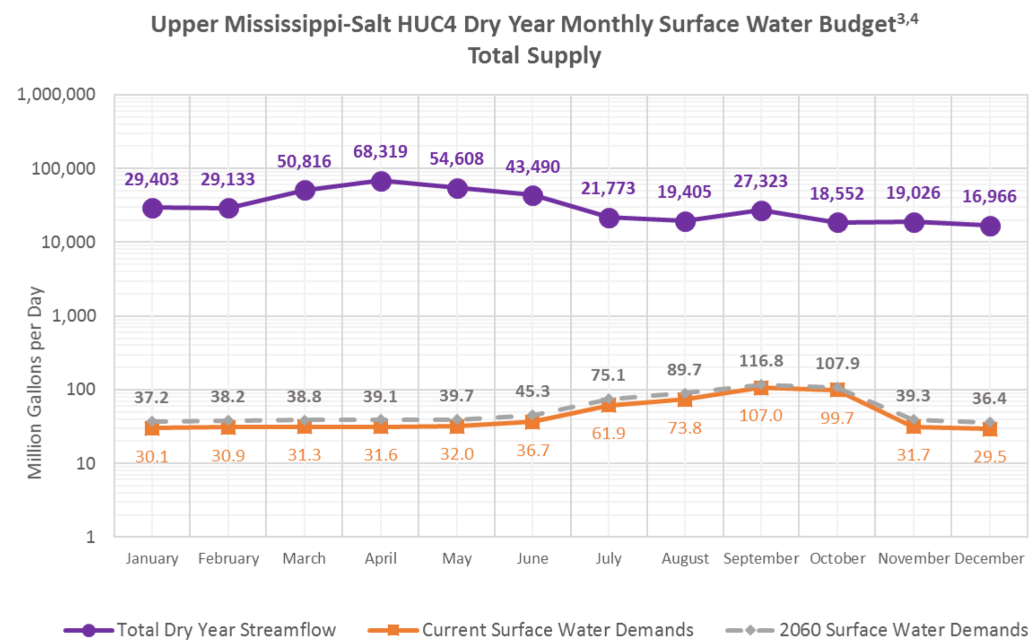
Monthly Comparisons of Supply and Demand

Out-of-State and Major River Supply Average Year



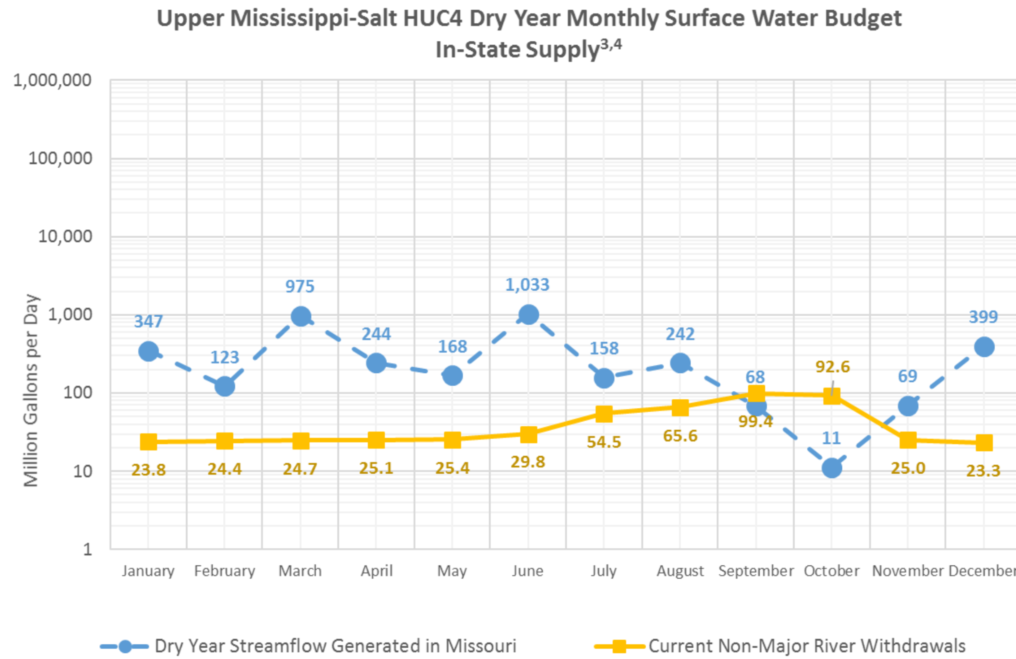
Upper Mississippi-Salt

Total Supply Dry Year



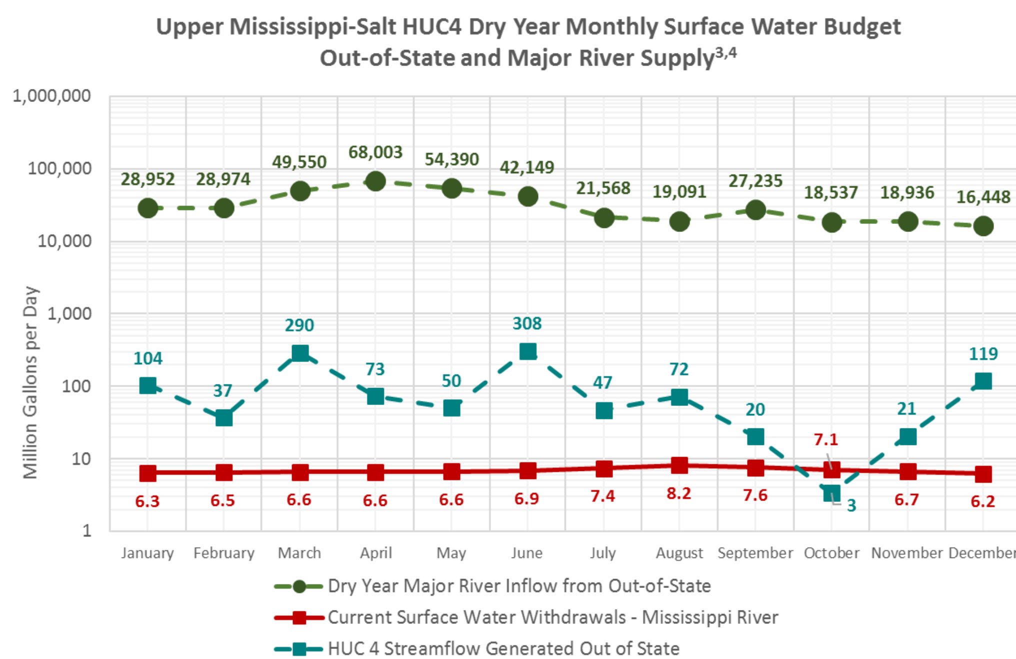
Monthly Comparisons of Supply and Demand

In-State Supply
Dry Year



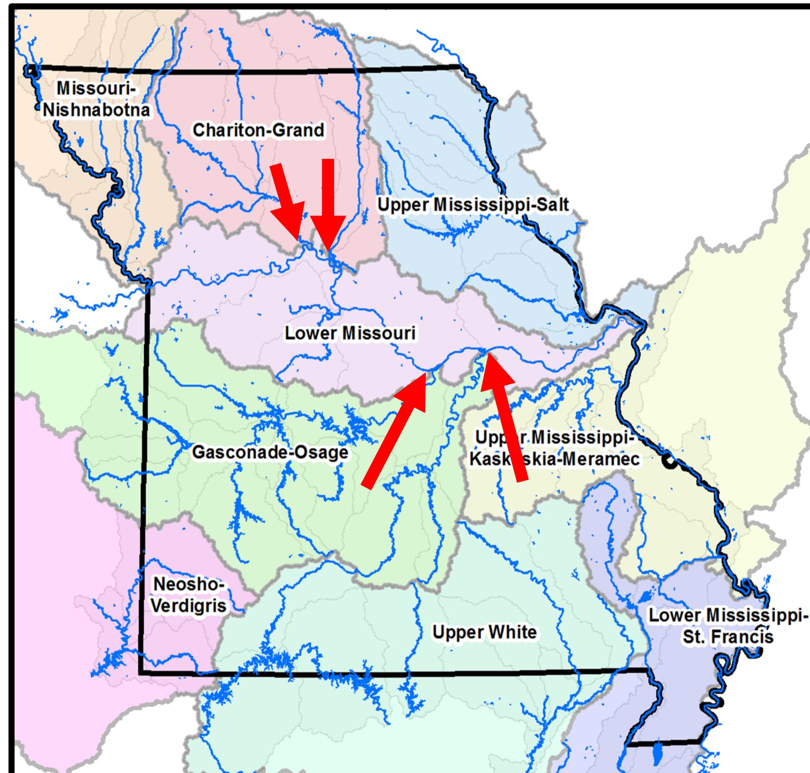
Upper Mississippi-Salt

Out-of-State and Major River Supply
Dry Year



What do the Monthly Comparisons Tell Us?

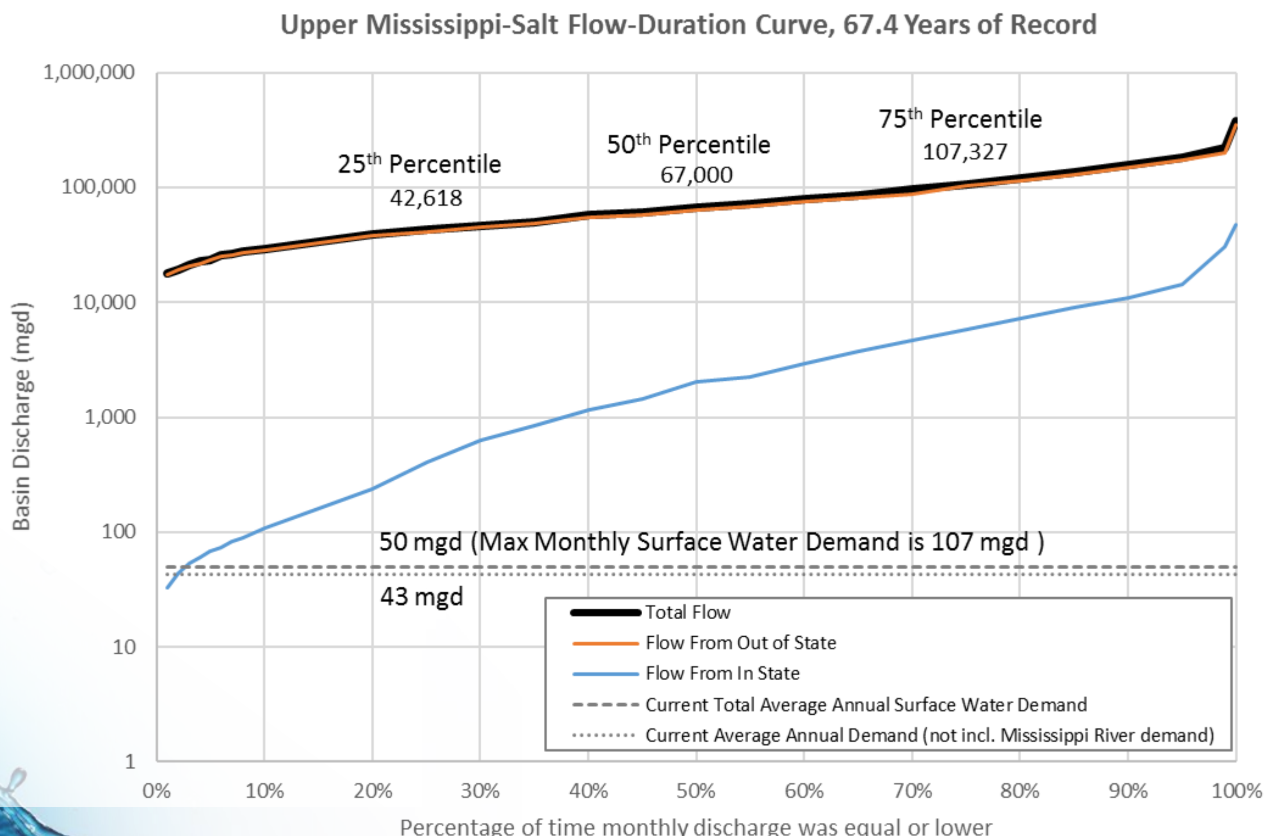
- Where demand exceeds supply, a gap exists
  - Generally, the state appears to have adequate supply
  - Only gap noted for Mississippi-Salt basin using dry year, in-state flows
  - This analysis looks at HUC4 as a whole, and gaps may exist further up in the watershed (infrastructure gaps)



Note: The Lower Missouri HUC4 has an additional in-state inflow, labelled as "In-state HUC4 inflows"

Flow-Duration Curves

- Useful for identifying frequency of potential shortage
- Mean monthly flow over entire period of record compared to average annual and maximum month demand

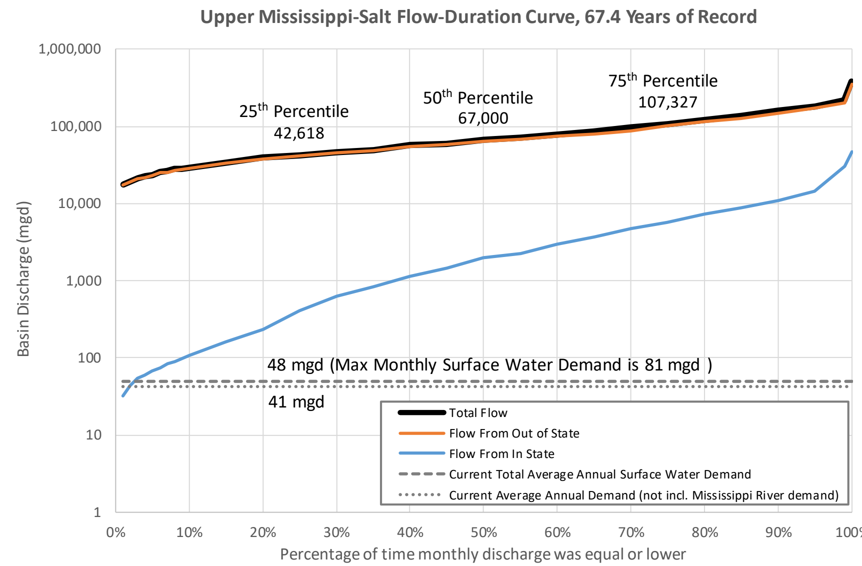


Note: Thermo demands are not included in surface water demands

HUC4 Basin Summaries

Upper Mississippi-Salt Basin Summary

Flow-Duration Curve[5]



Note: Thermo demands are not included in surface water demands

Water Supply Reservoir Storage[6]

	Water Supply Storage ac-ft	Water Supply Storage Mgal	Optimum Yield (mgd)	HUC8
Lake Show Me (Memphis)	4,125	1,344	0.78	7110002
Old City Lake (Memphis)	220	72	0.10	7110002
East Lake (Bowling Green)	1,240	404	0.36	7110004
West Lake (Bowling Green)	460	150	0.24	7110004
Lake (Shelbina)	406	132	0.27	7110005
Rt. J Lake (Monroe City)	1,245	406	1.01	7110007
Vandalia Lake (Vandalia)	317	103	0.33	7110008
Mark Twain Lake	20,000	6,517	16.00	7110005,6,7
Total	**28,013**	**2,611**	**19.09**	

	Months of Storage with Minimum 30-Yr Inflow & No Outflow	Months of Storage with No Net Inflow
All Water Supply Reservoirs in Basin	63	25

MISSOURI WATER RESOURCES PLAN

Reservoir Analysis

- Mass-balance accounting for total storage in each HUC4 basin using minimum year inflow and evaporation
- Assumes reservoirs are full at beginning of low-flow period
- Does not account for demands upstream of reservoirs

HUC4	Name	Number of Public Supply Reservoirs	Total Lake Storage *mgal*	Annual Demand from Reservoirs (2011) *mgd*	Average Year Inflow *mgd*	Minimum Year Inflow[1] *mgd*	Loss to Evaporation[2] *mgd*	Net Loss(-) or Gain, with Minimum Year Inflow *mgd*	Months of Storage with Minimum Year Inflow & No Outflow	Months of Storage with No Net Inflow
711	Upper Mississippi-Salt	7	2,611	7.0	13.1	2.1	1.4	-6.37	**13**	**10**
714	Upper Mississippi-Kaskaskia-Meramec		*No Reservoirs for Public Water Supply*							
802	Lower Mississippi-St. Francis	2	165	0.2	1.8	0.8	0.2	0.47	***reservoirs do not empty***	**15**
1024	Missouri-Nishnabotna	2	36,747	3.3	108.2	14.5	3.0	8.24	***reservoirs do not empty***	**193**
1028	Chariton-Grand	32	31,512	15.5	124.4	14.5	14.3	-15.37	**67**	**35**
1029	Gasconade-Osage	7	31,085	32.5	8,326	1,870	1.9	1,836	***reservoirs do not empty***	**30**
1030	Lower Missouri	6	4,072	4.8	18.9	2.9	3.4	-5.31	**25**	**16**
1101	Upper White		*No Reservoirs for Public Water Supply (except Lake Taneycomo)*							
1107	Neosho-Verdigris	1	515	0.5	3.0	0.6	0.5	-0.35	**48**	**18**

1. Minimum 30-year annual flow (1987-2016).
2. Based on average annual free surface evaporation. Inflow from preciptation on lake surface not estimated.

Surface Water Supply and Demand by HUC8 Basin

- Supply for each HUC4 applied to HUC8 basins
  - Additional analysis necessary to differentiate supply in HUC8 basins
- Useful for identifying where both current and future demands are highest and prioritizing HUC8 basins for further assessment
- To help identify gaps/stress, can also compare:
  - Current and future average annual demands to available streamflow
  - Current and future peak monthly demands to available streamflow
  - Current and future demands to dry year streamflow

HUC4 Basin Summaries

Upper Mississippi-Salt Basin Summary

Summary of Surface Water Demands by HUC8

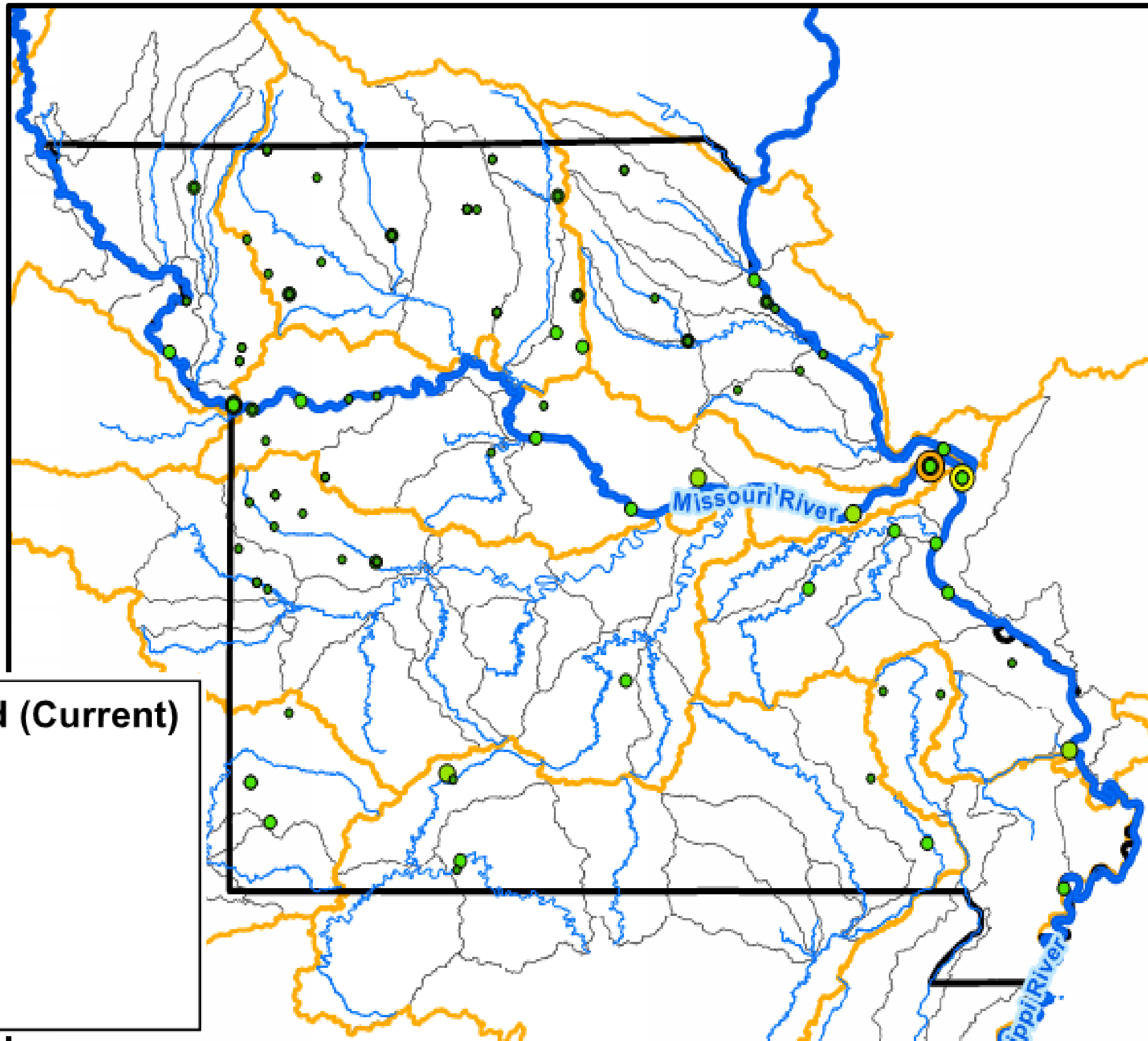
HUC8 Basin Name	HUC8 Number	Area (MO) sq miles	Current Demand in/yr	Current Demand mgd
Bear-Wyaconda	7110001	798	0.03	1.27
North Fabius	7110002	815	0.05	1.84
South Fabius	7110003	619	0.04	1.08
The Sny	7110004	1,016	0.37	17.88
North Fork Salt	7110005	893	0.19	7.89
South Fork Salt	7110006	1,213	0.12	6.69
Salt	7110007	794	0.06	2.32
Cuivre	7110008	1,262	0.05	3.02
Peruque-Piasa	7110009	354	27.06	455.04
	Total	**7,764**	**27.96**	**497.0**

Notes

1. Sioux power generation facility in St. Charles County is scheduled to be retired in 2033.
2. Groundwater demands include alluvial and groundwater aquifer withdrawals
3. Comparisons of monthly surface water availability to demands do not include thermo demands.
4. Dry year streamflow represents the lowest annual streamflow over the period from 1985-2016. For this HUC4 basin, the lowest annual streamflow was 1989 (gage 05501000), 1956 (gage 05502500), and 2006 (gage 05514500).
5. Demands shown on flow duration curve do not include thermo demands.
6. Reservoir data sources and notes:
   a. *Missouri Water Supply Study, Missouri DNR, June 2011*
   b. *US Army Corps of Engineers, Institute for Water Resources. (2014). Fiscal Year 2014 Value to the Nation Fast Facts Water Supply. Retrieved from http://www.corpsresults.us/*
   c. In addition to Rt J. Lake, Monroe City's water supply may also be supplemented by a smaller lake, South Lake. Information on South Lake was not availalable, and thus not included in this summary.

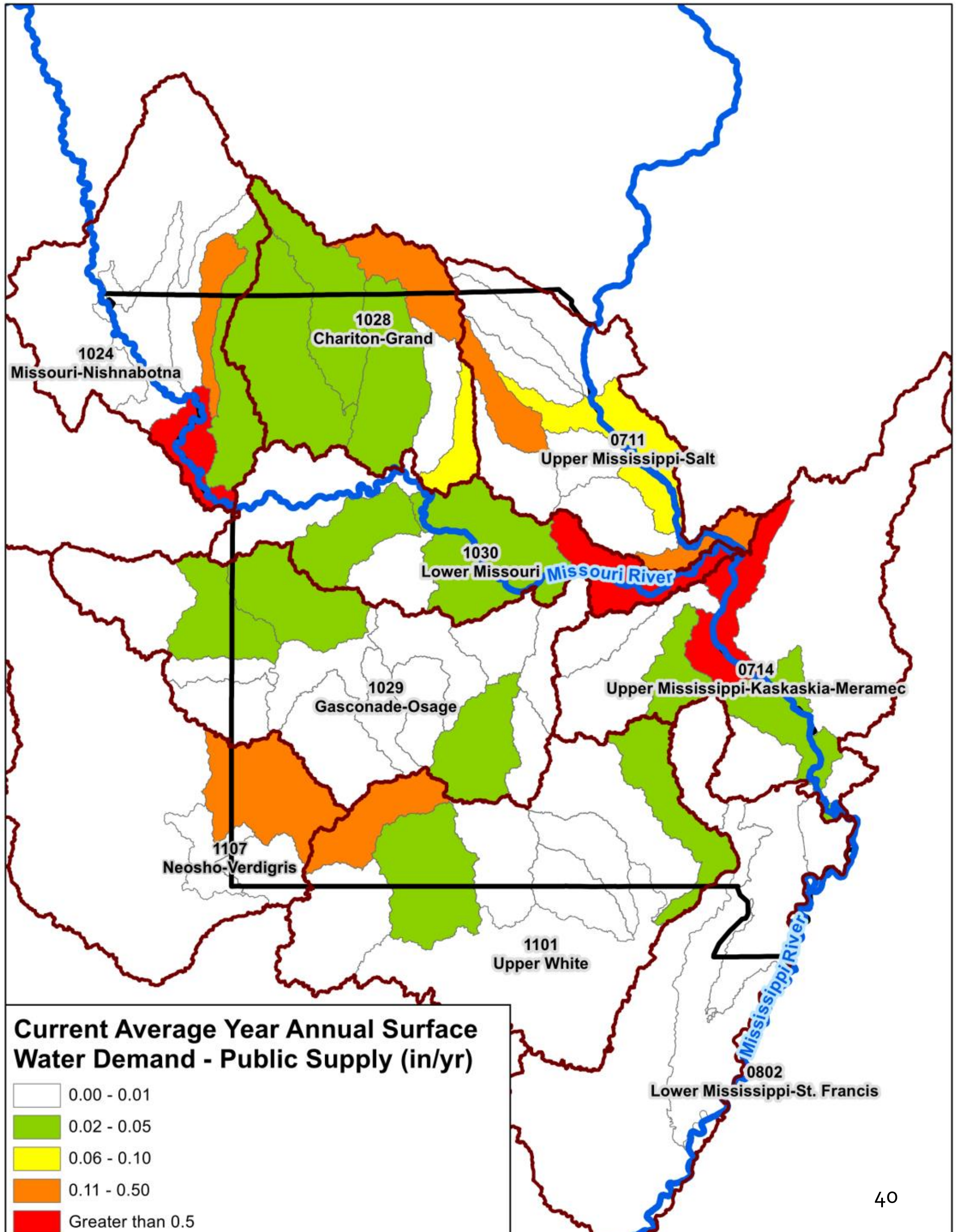
MISSOURI WATER RESOURCES PLAN

Current Average Annual Surface Water Demand for Public Supply, Thermoelectric (Net Use), and Non-Residential Self-Supply Sectors



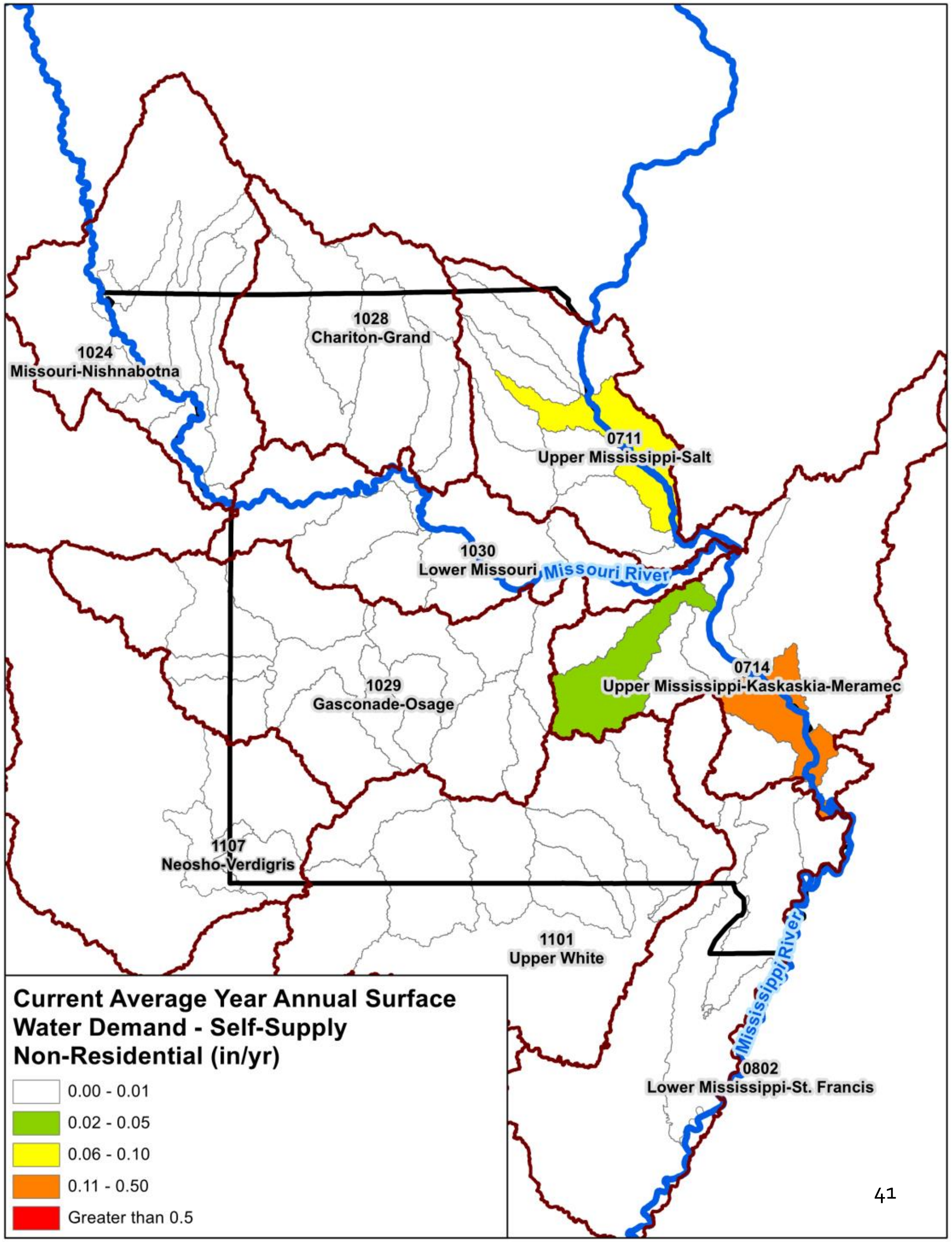
MISSOURI WATER RESOURCES PLAN

Current Average Annual Surface Water Demand for Public Supply



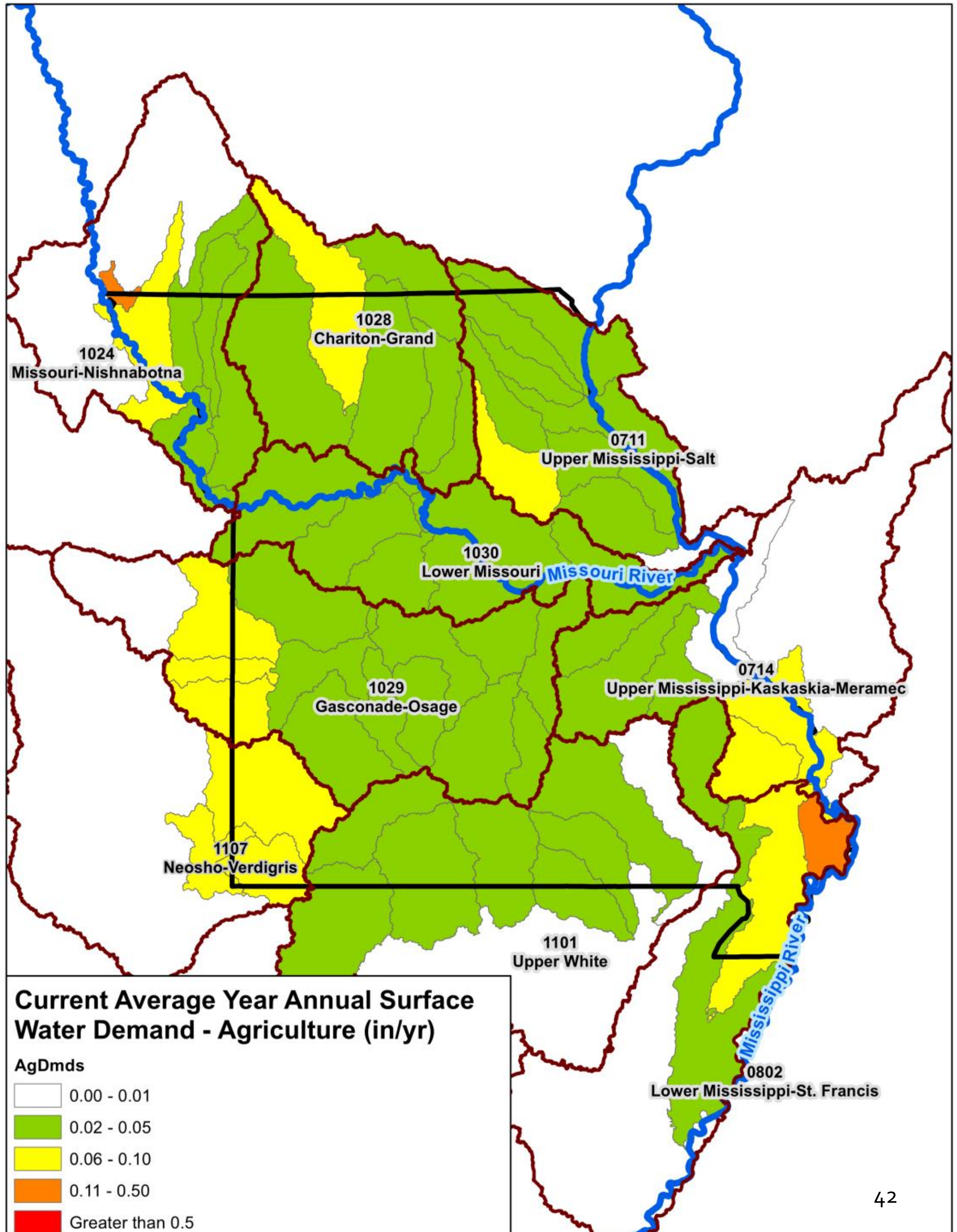
MISSOURI WATER RESOURCES PLAN

Current Average Annual Surface Water Demand for Self-Supply Non-Residential



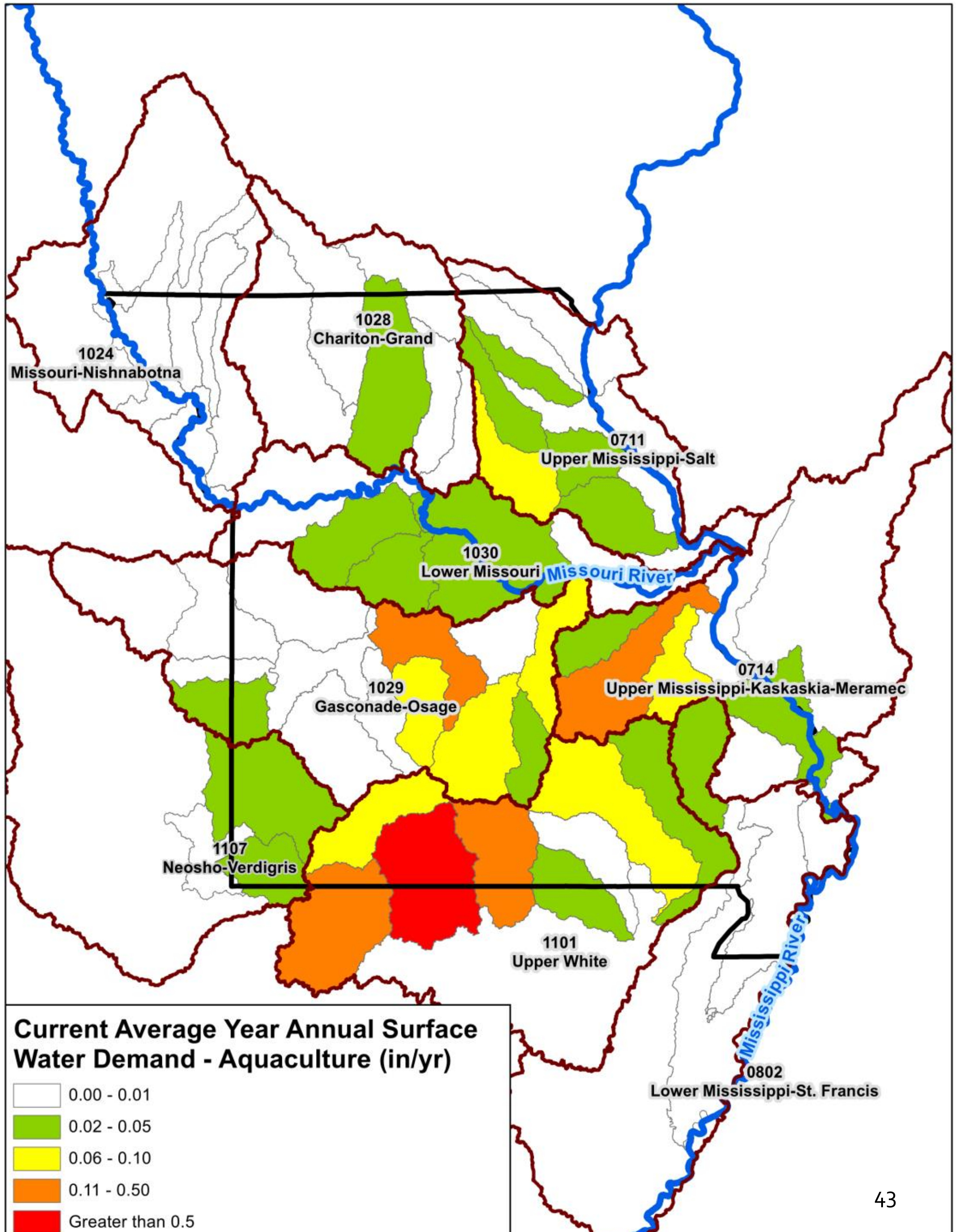
MISSOURI WATER RESOURCES PLAN

Current Average Annual Surface Water Demand for Agriculture



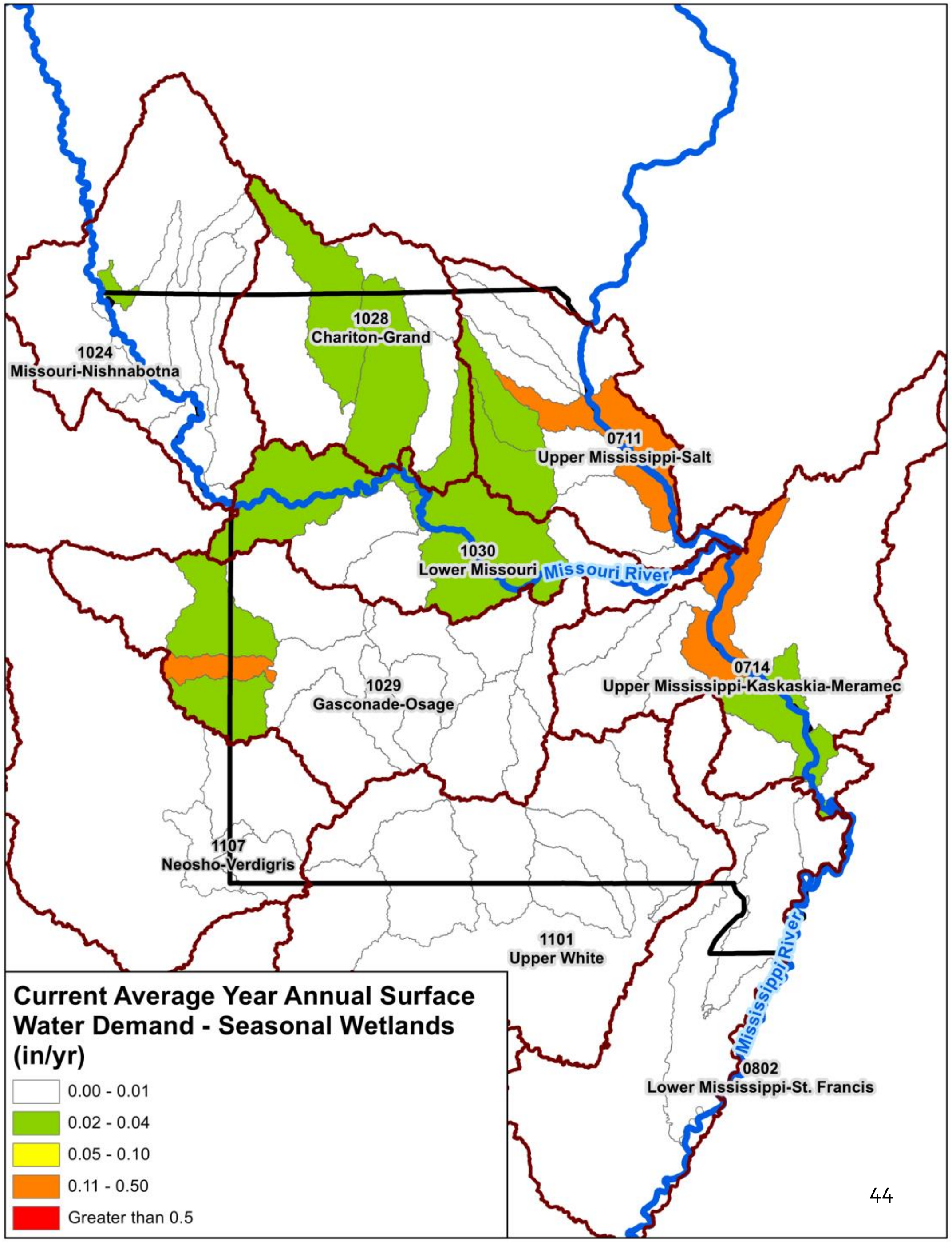
MISSOURI WATER RESOURCES PLAN

Current Average Annual Surface Water Demand for Aquaculture



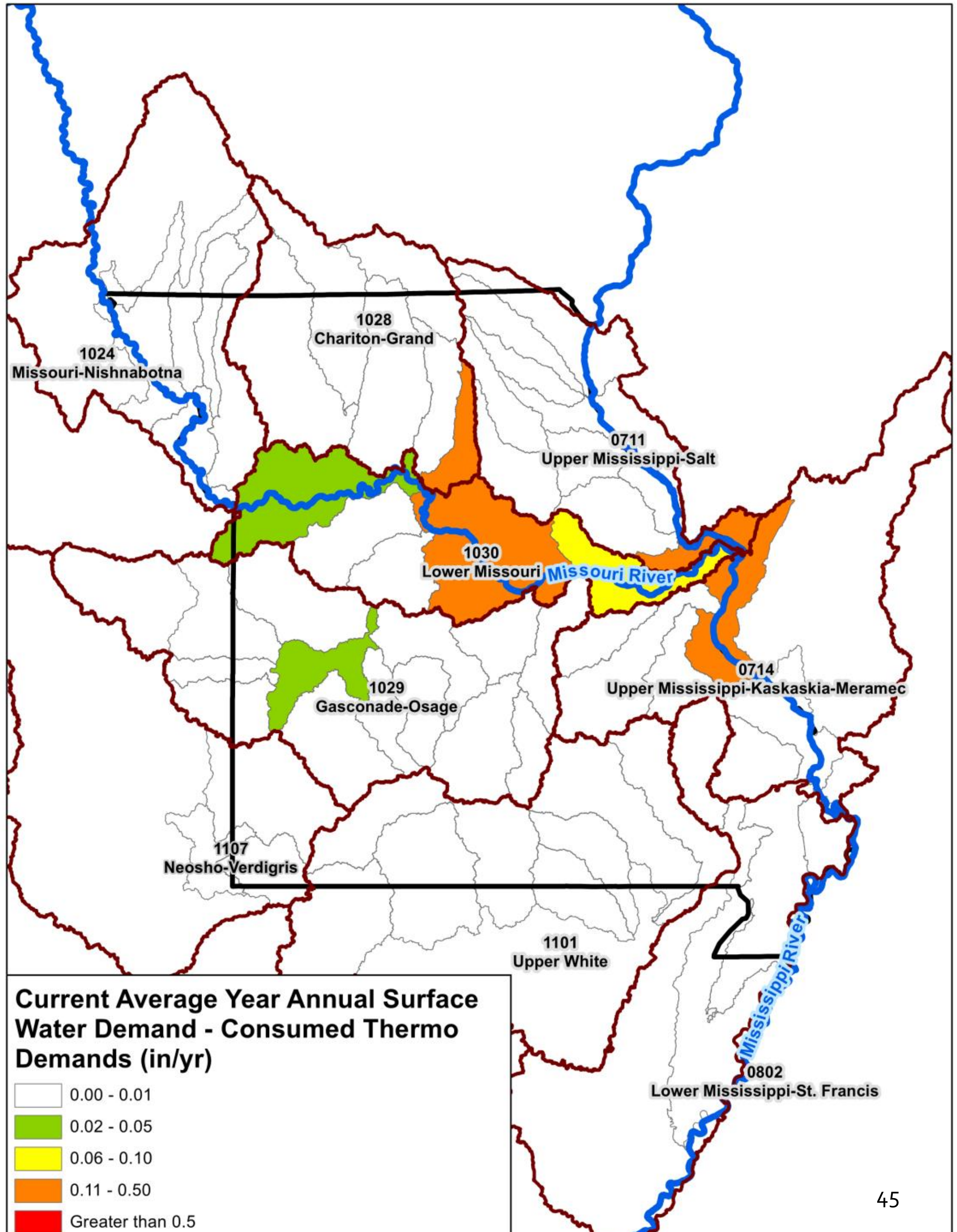
MISSOURI WATER RESOURCES PLAN

Current Average Annual Surface Water Demand for Seasonal Wetlands

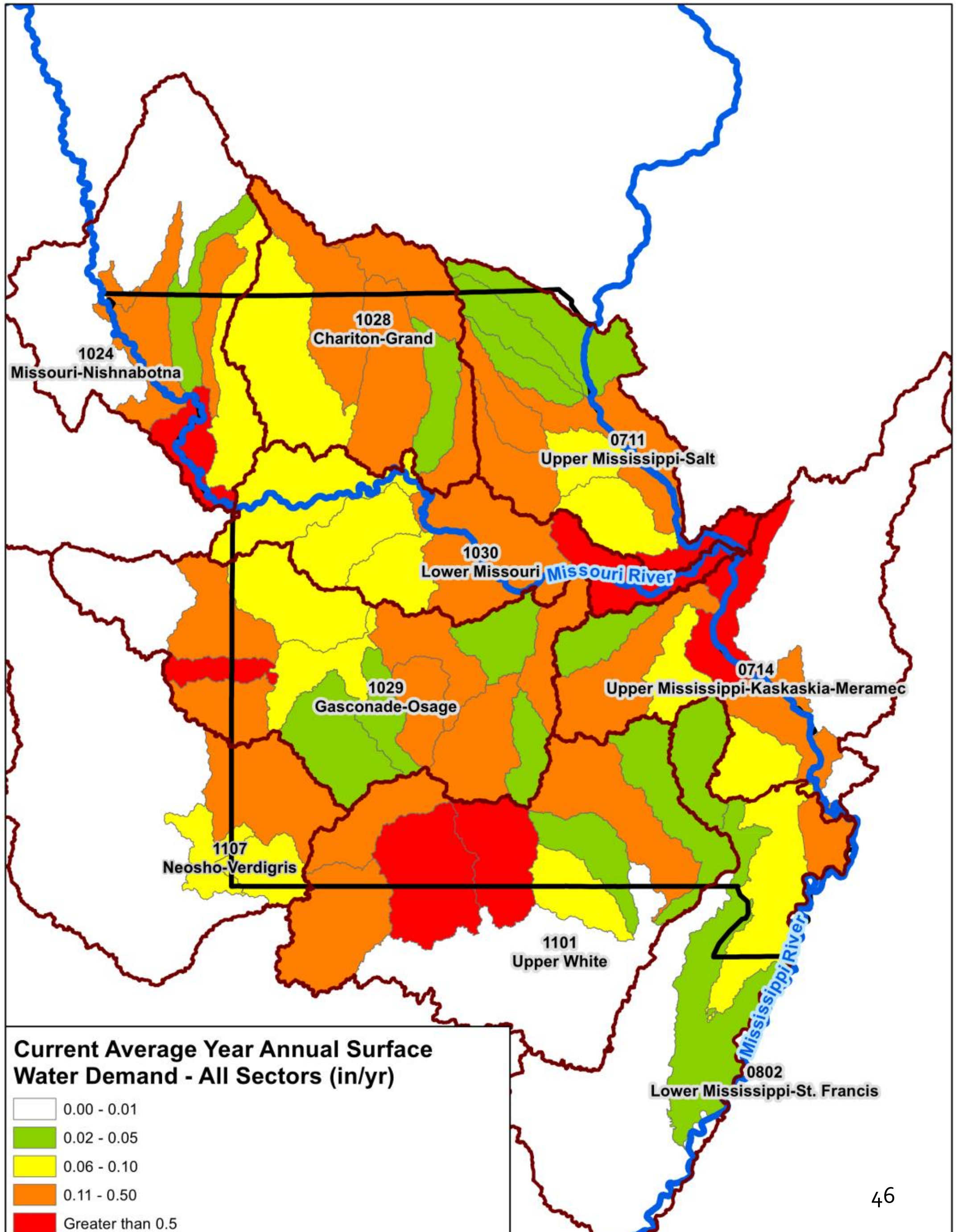


MISSOURI WATER RESOURCES PLAN

Current Average Annual Surface Water Net Demand for Thermoelectric Power Generation

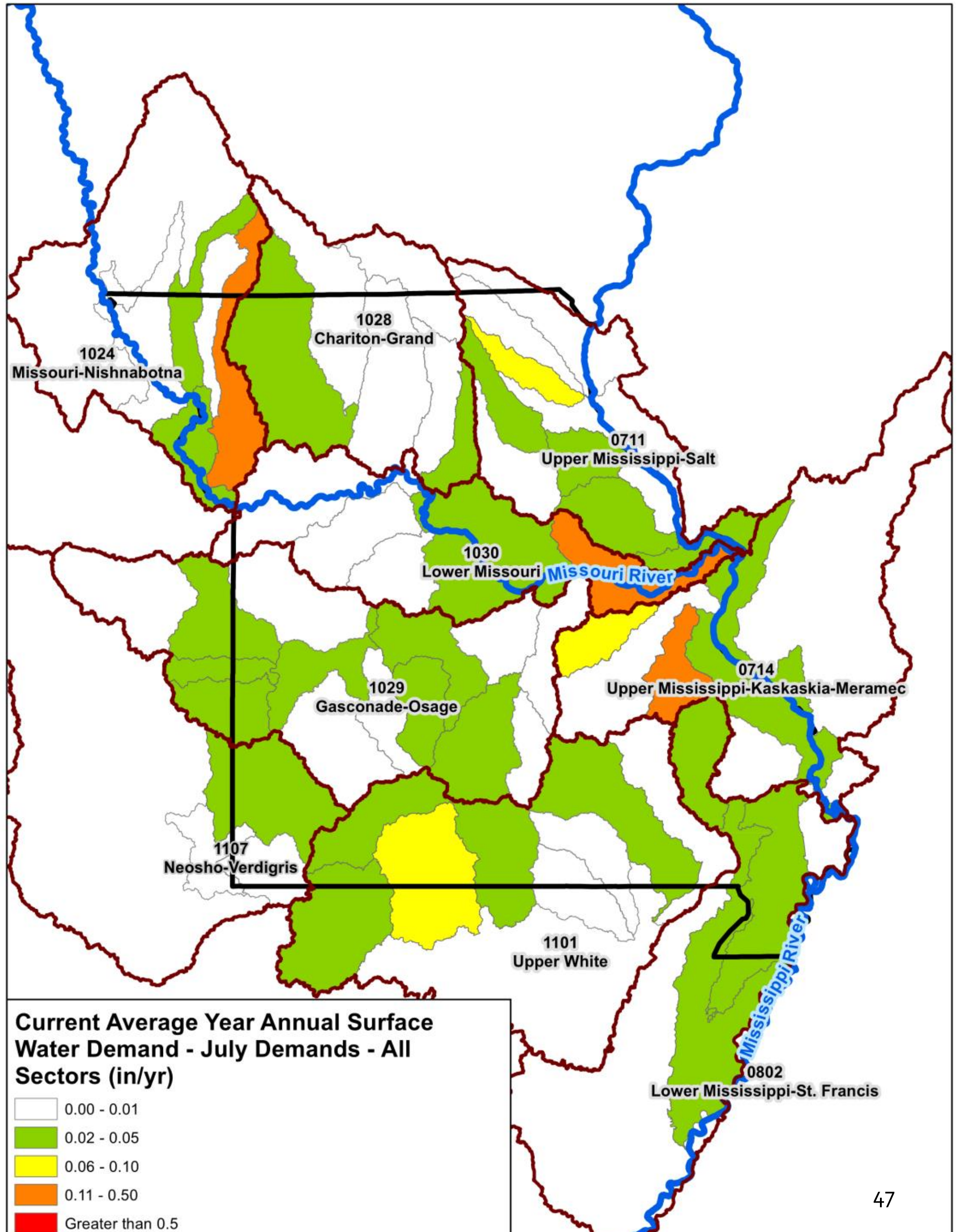


Current Average Annual Surface Water Demand for All Water Use Sectors



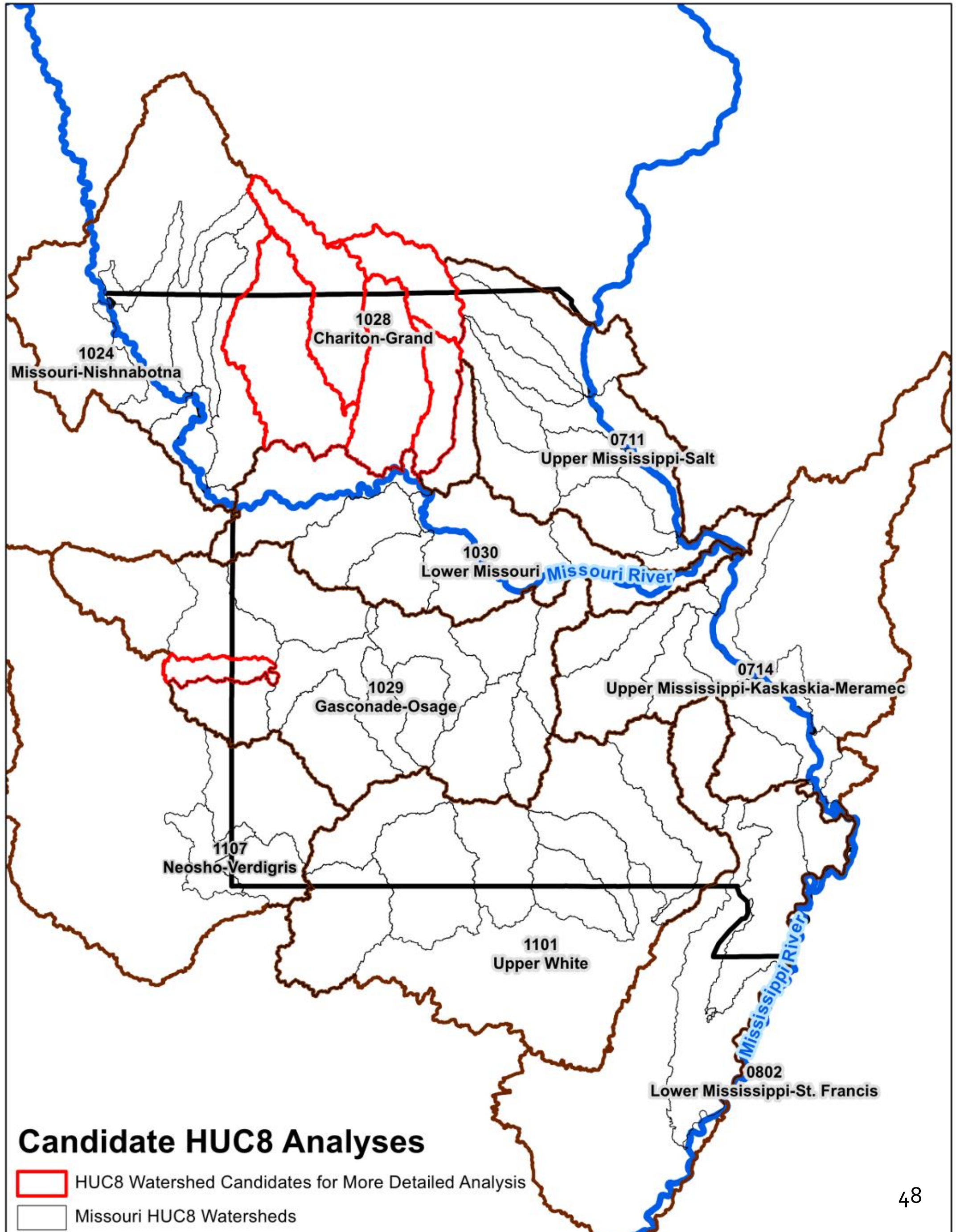
MISSOURI WATER RESOURCES PLAN

Current July Surface Water Demand for All Water Use Sectors



MISSOURI WATER RESOURCES PLAN

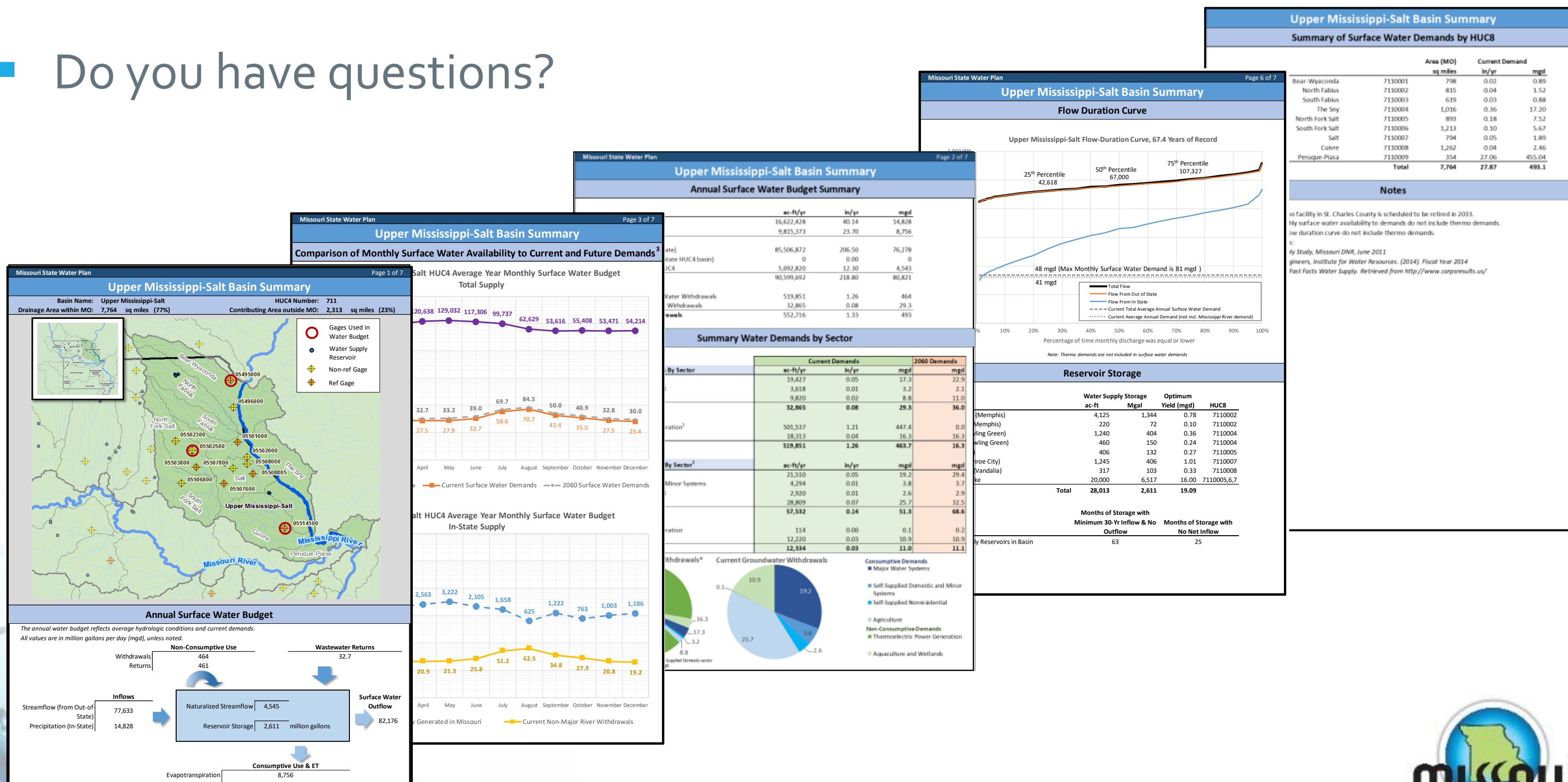
HUC8 Watersheds Identified as Candidates for More Detailed Analysis



MISSOURI WATER RESOURCES PLAN

Homework

- Review HUC4 Basin Summary Sheets
  - Are they understandable?
  - Are there any notable omissions?
  - Do you have questions?



Surface Water Supply Analysis Discussion

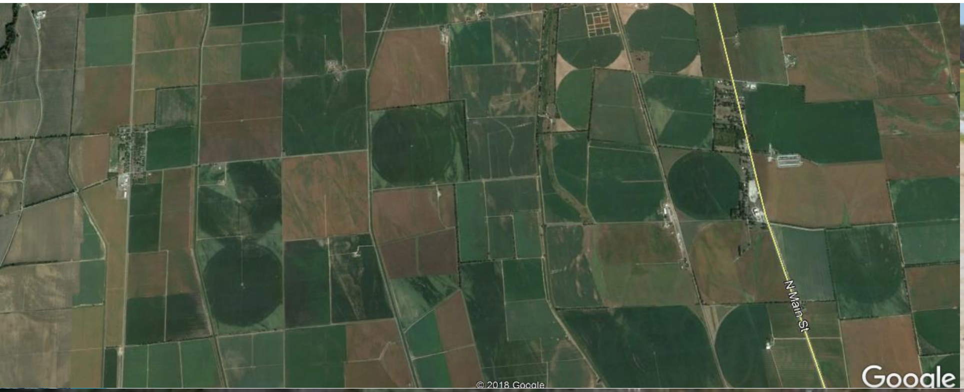
Next Steps

- Identify HUC8 basins for further study
- Complete groundwater supply analysis and update water budgets, to the extent possible
- Conduct scenario planning

Agricultural Needs

Objectives

- Evaluate current water use of irrigated crops and livestock by county in Missouri
- Project volume of water needed for irrigation and livestock through 2060



Estimating Irrigation Water Use

- Define acreage irrigated in each county
- Determine water use for each crop

Availability of Irrigation Data

- Most agriculture water users not metered
- Several overlapping and/or incomplete estimates of irrigated acreages and water use

Water Use Assumptions

- Irrigation applied to meet site-specific crop water demand
- Water demand equals the difference between plant *evapotranspiration* and *effective precipitation*

Crops Irrigated






Crops Irrigated






Irrigation Efficiency

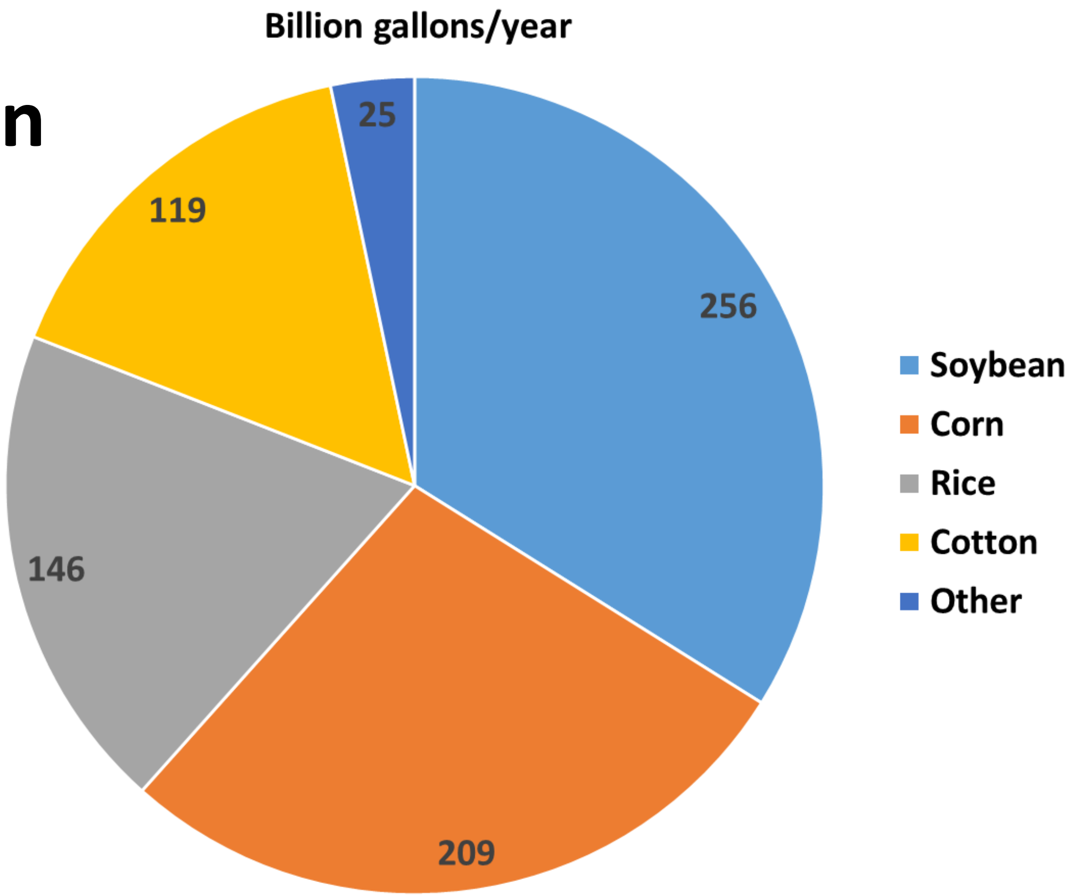
- USGS lists county's proportion of use for each method



Irrigation – Current Crop Water Use

DRAFT RESULTS

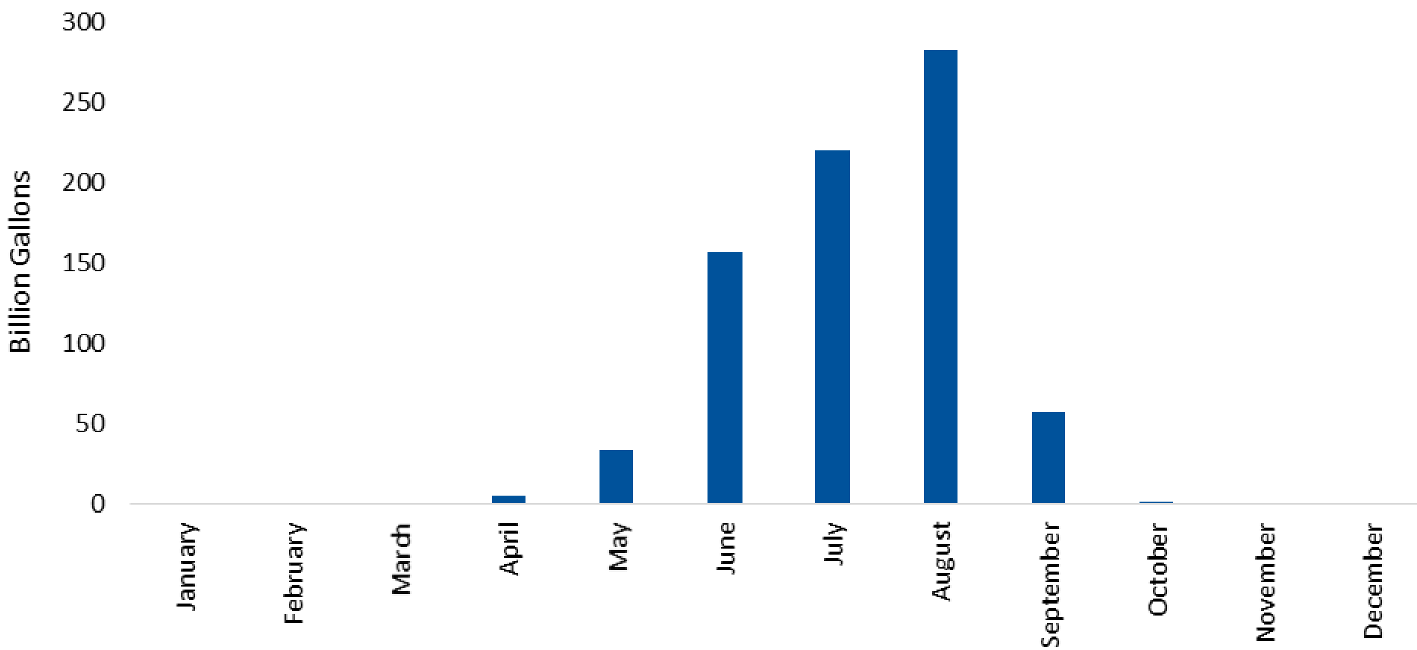
756 Billion gallons



MISSOURI WATER RESOURCES PLAN

Irrigation– Current Use Monthly Demands

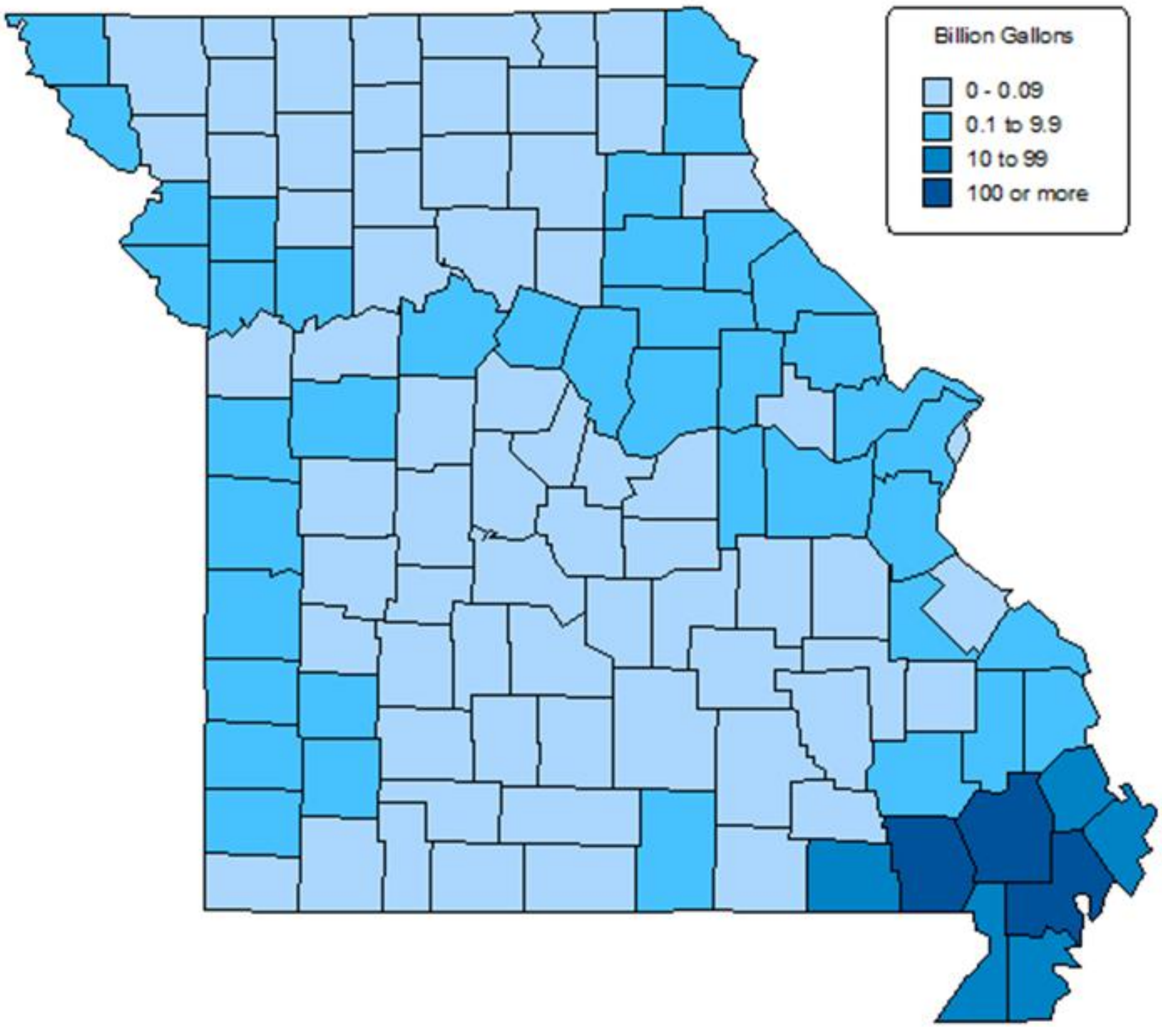
DRAFT RESULTS



MISSOURI WATER RESOURCES PLAN

Irrigation – Current Use Spatial Water Demands

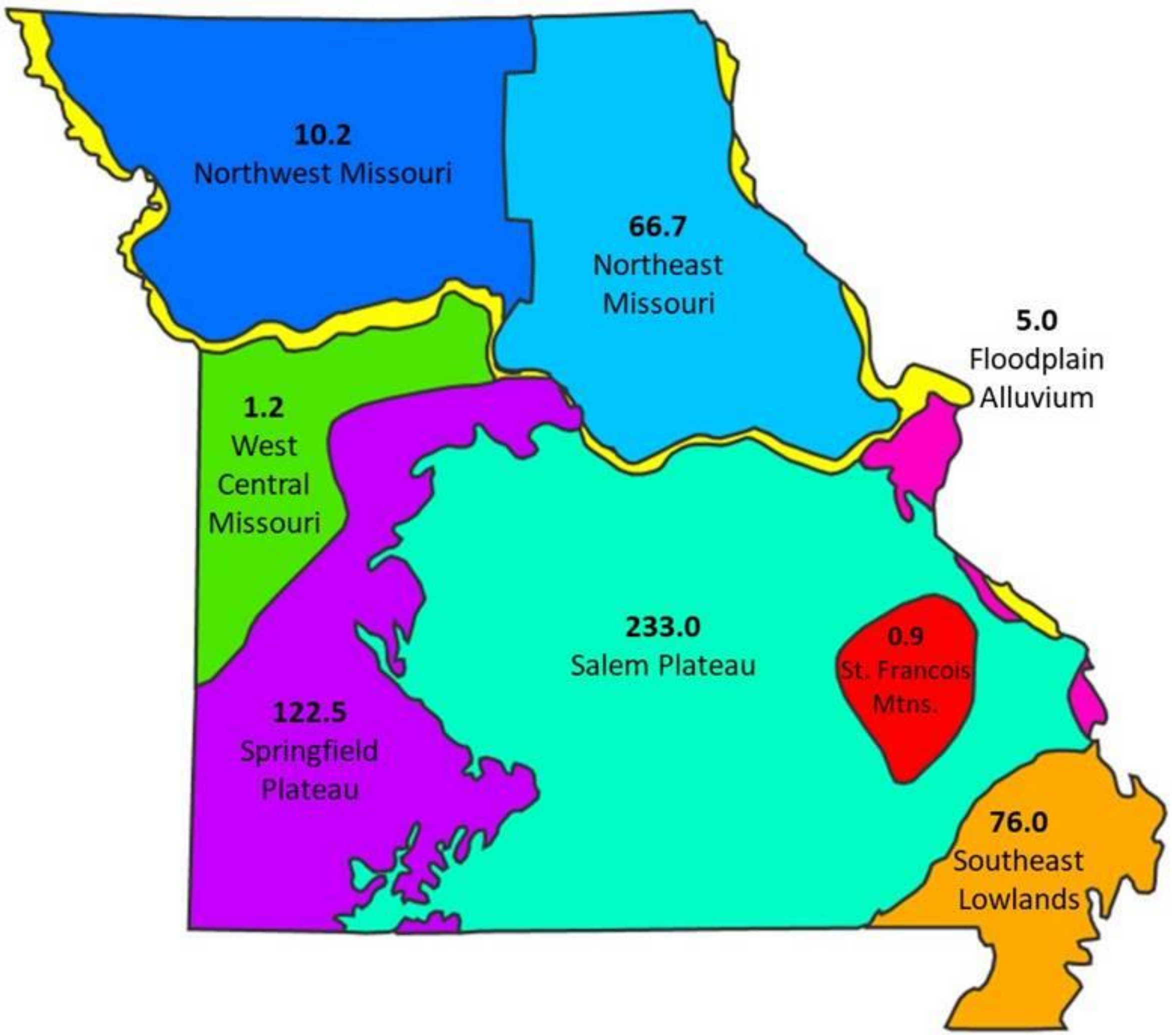
DRAFT RESULTS



MISSOURI WATER RESOURCES PLAN

Perspective Is Important-515 TRILLION Gallons Estimated In Groundwater Storage

DRAFT RESULTS



MISSOURI WATER RESOURCES PLAN

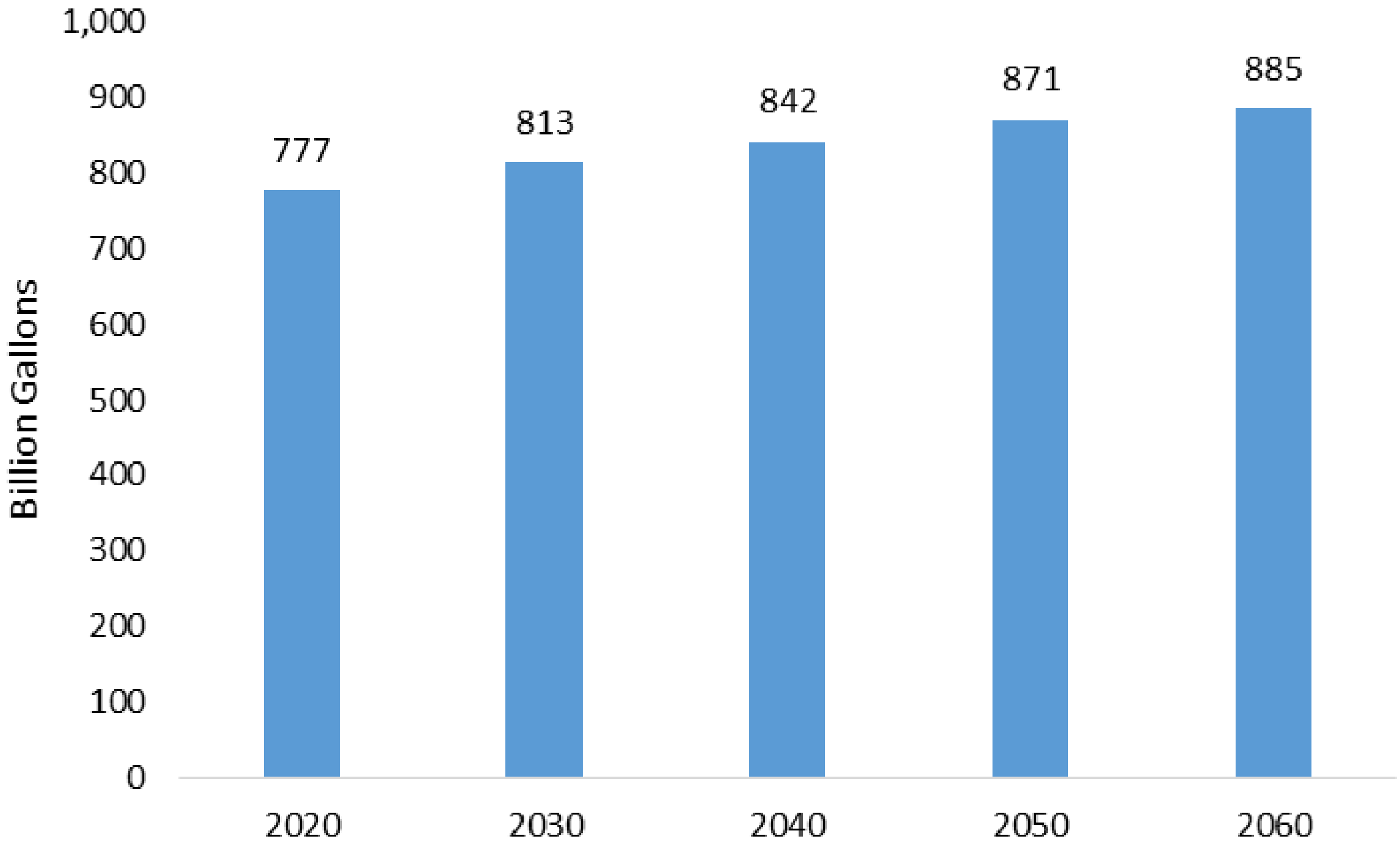
Perspective Is Important

- At current irrigation use rates, groundwater storage supplies almost 700 years of water
- Here's how civilizations irrigated 700 years ago…

Perspective Is Important

Irrigation – Future Use Projections

DRAFT RESULTS



Irrigation– Future Use Projections

DRAFT RESULTS

	Irrigation Demand (billion gallons)					
HUC Source	2016	2020	2030	2040	2050	2060
Chariton-Grand	0.2	0.2	0.2	0.3	0.3	0.3
Des Moines	0.1	0.1	0.1	0.1	0.1	0.1
Gasconade-Osage	7.9	8.1	8.5	8.8	9.1	9.3
Kansas	0	0	0	0	0	0
Lower Mississippi-Hatchie	8.5	8.7	9.2	9.5	9.8	10.0
Lower Mississippi-St. Francis	578.0	594.0	622.0	644.0	666.0	677.0
Lower Missouri	3.6	3.7	3.9	4.0	4.2	4.2
Missouri-Nishnabotna	11.6	11.9	12.4	12.9	13.3	13.5
Neosho-Verdigris	5.5	5.6	5.9	6.1	6.3	6.4
Upper Mississippi-Kaskaskia-Meramec	19.6	20.1	21.0	21.8	22.5	22.9
Upper Mississippi-Salt	8.7	8.9	9.3	9.7	10.0	10.2
Upper White	112.2	115.4	120.7	125.0	129.3	131.4

MISSOURI WATER RESOURCES PLAN

Assessing Animal Water Needs

- Census of Agriculture provides no water use data for livestock
- Assessment based on livestock in each county

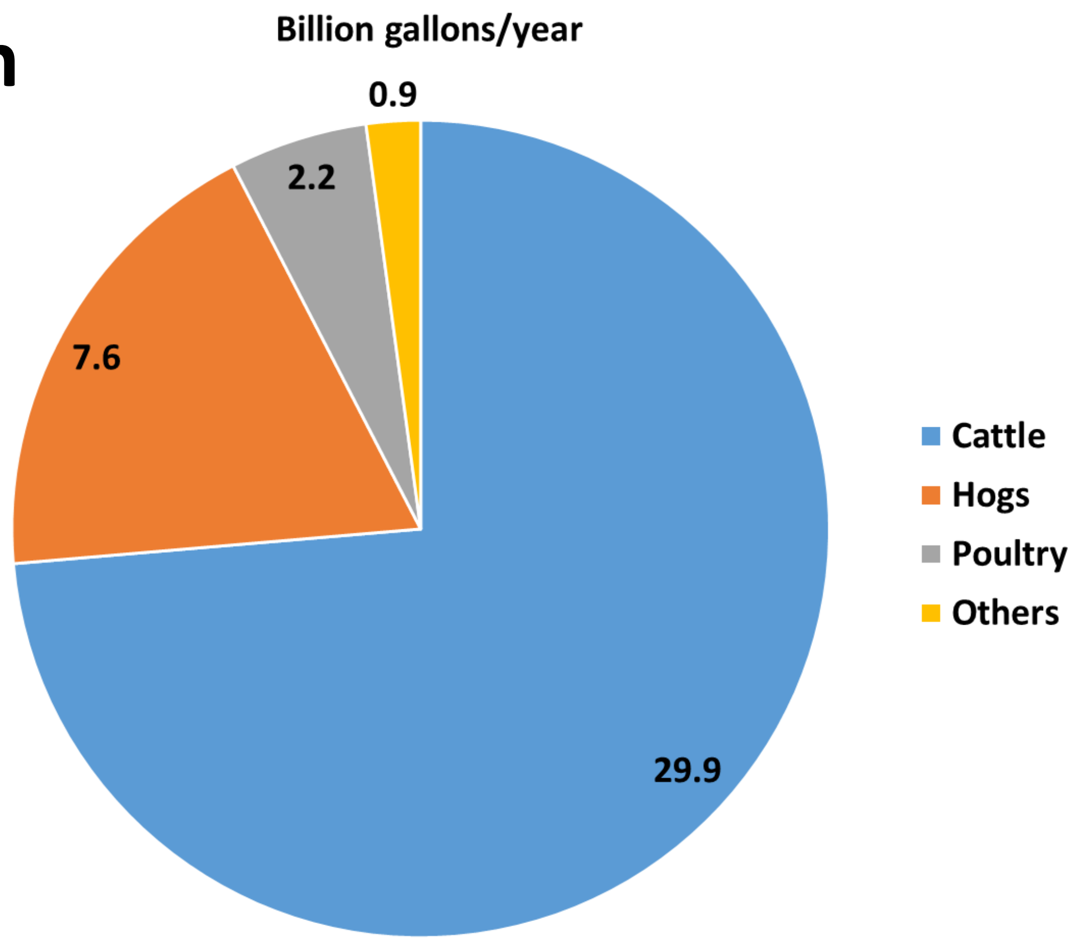
Livestock Water Use Assumptions

- Livestock water demand calculated on a daily basis
  - Sources included NRC, USGS, MU Extension, NDSU Extension
- Each livestock category has a fixed number of water-use days per year


Livestock – Current Water Use

DRAFT RESULTS

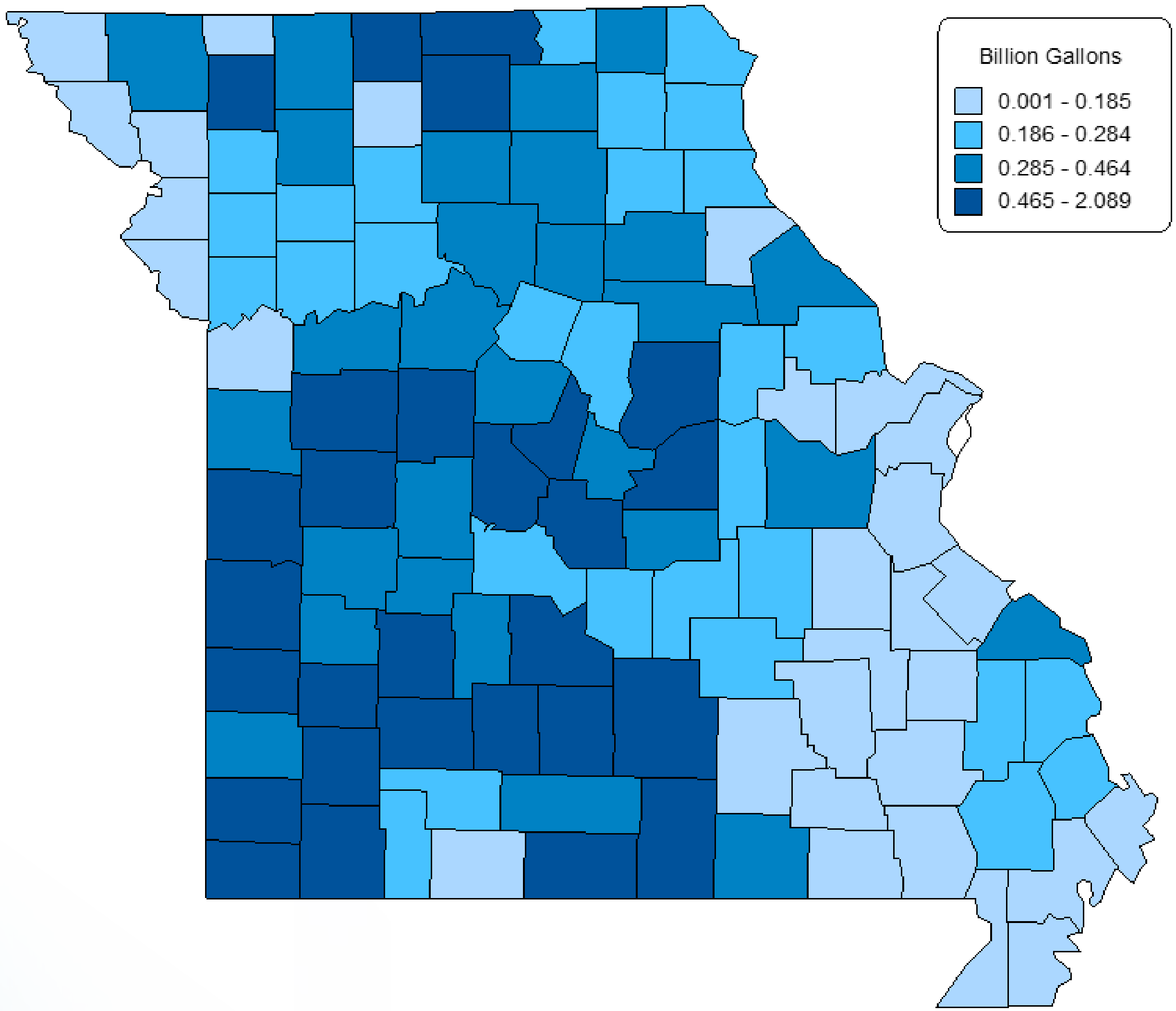
41 Billion gallons



MISSOURI WATER RESOURCES PLAN

Livestock – Current Spatial Water Use

DRAFT RESULTS



MISSOURI WATER RESOURCES PLAN

Livestock – Regional Groundwater Reliance

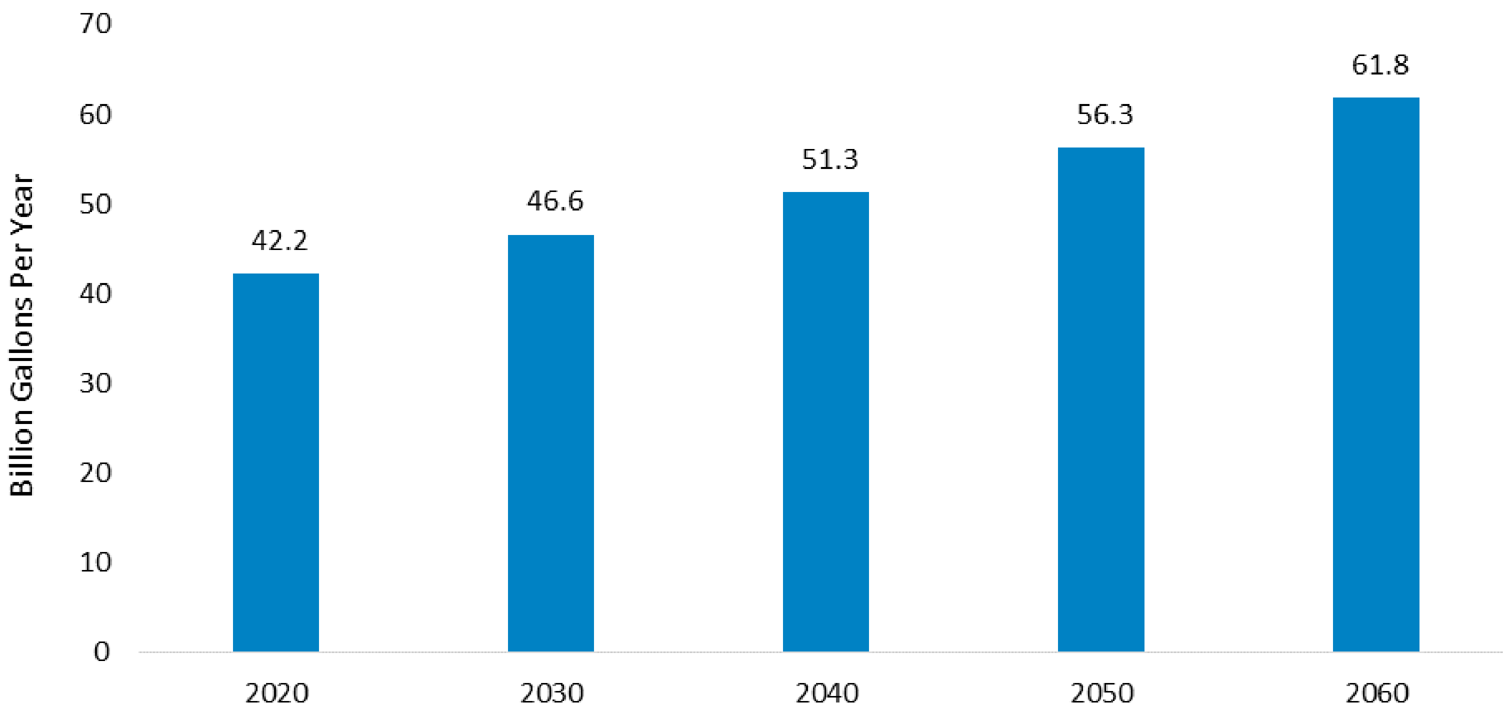
DRAFT RESULTS

- Generally, a latitudinal gradient exists in Missouri
- Based on groundwater availability and development of grazing systems
- In southern third about 30% of livestock water comes from wells
- In middle third groundwater supplies about 25% of livestock water
- In the northern third, only 10-15% of livestock water comes from wells

MISSOURI WATER RESOURCES PLAN

Livestock – Future Use Projections

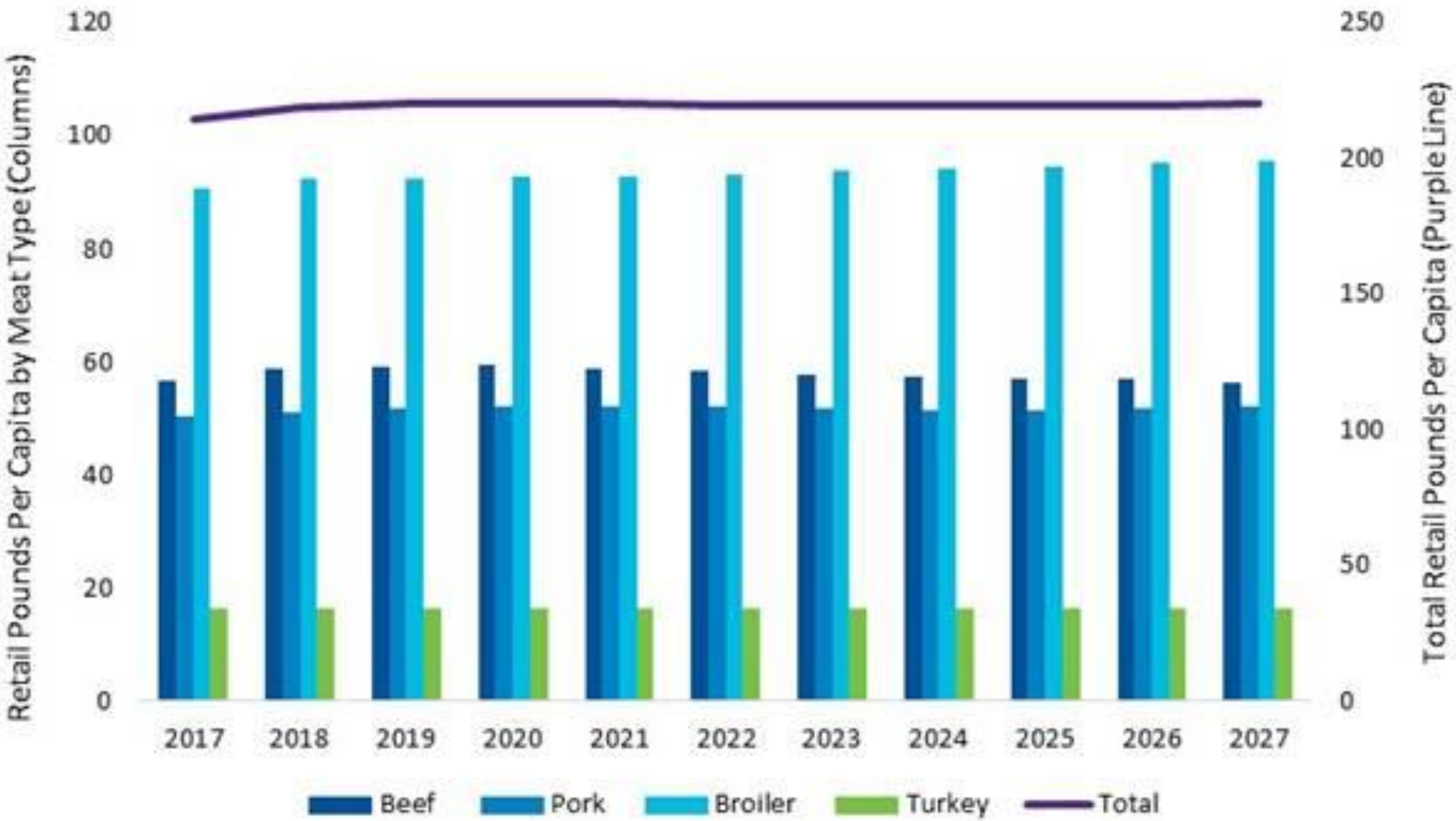
DRAFT RESULTS



MISSOURI WATER RESOURCES PLAN

Protein Demand Drives Industry Growth

DRAFT RESULTS



MISSOURI WATER RESOURCES PLAN

Livestock – Future Use Projections

DRAFT RESULTS

	Livestock Demand (billion gallons)					
HUC Source	2016	2020	2030	2040	2050	2060
Chariton-Grand	6.6	6.8	7.4	8.0	8.7	9.4
Des Moines	0.02	0.03	0.03	0.03	0.03	0.04
Gasconade-Osage	11.7	12.1	13.4	14.7	16.1	17.7
Kansas	0	0	0	0	0	0
Lower Mississippi-Hatchie	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Lower Mississippi-St. Francis	0.7	0.7	0.8	0.9	1.0	1.1
Lower Missouri	6.4	6.7	7.4	8.1	9.0	9.8
Missouri-Nishnabotna	1.2	1.2	1.3	1.5	1.6	1.8
Neosho-Verdigris	3.6	3.9	4.3	4.9	5.4	6.0
Upper Mississippi-Kaskaskia-Meramec	2.4	2.5	2.8	3.0	3.4	3.7
Upper Mississippi-Salt	3.6	3.8	4.1	4.5	4.9	5.4
Upper White	4.4	4.6	5.1	5.7	6.3	7.0

MISSOURI WATER RESOURCES PLAN

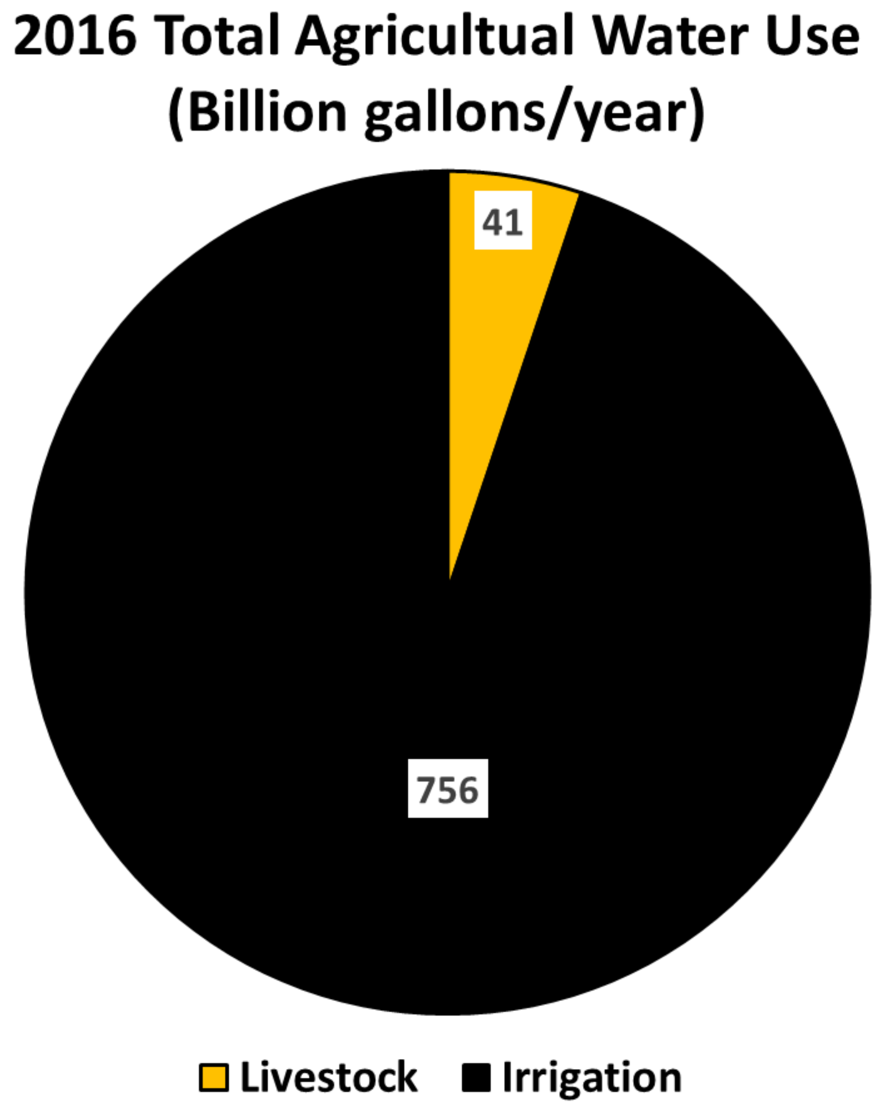
Let's Comprehend the Amount

- Livestock use 15% less water than the residents of St. Louis, Kansas City, and Springfield use annually


Combined Current Use Estimates

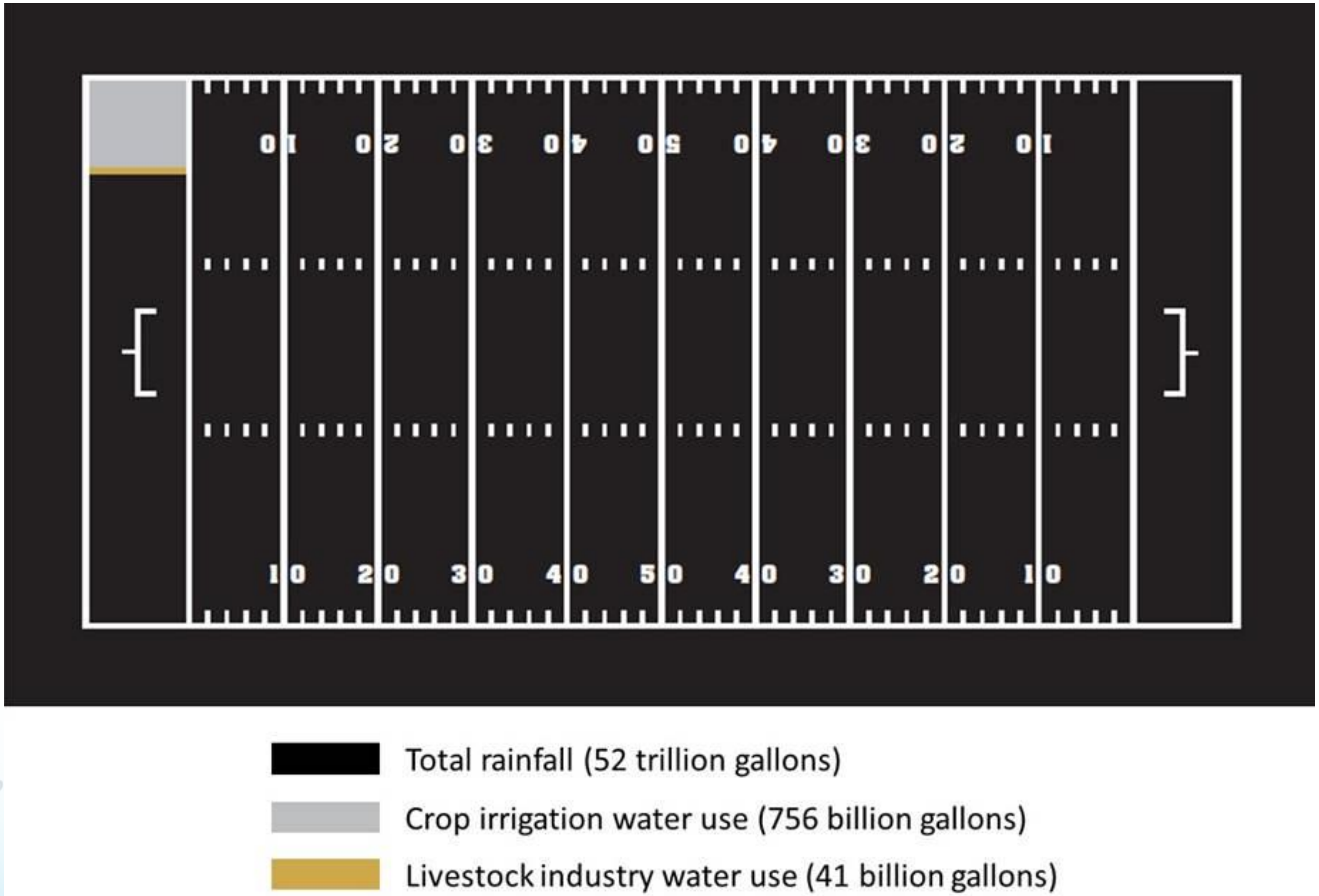
DRAFT RESULTS

797 Billion gallons



Thinking like a Tiger

- Another perspective…



MISSOURI WATER RESOURCES PLAN

Conclusions

- By 2060, livestock demand totals 62 billion gallons, a 50% increase from 2016
- Crop irrigation demand increases 17% from 756 to 885 billion gallons in the same time period
- Surface water supplies 2/3 of water required for livestock
- Groundwater supplies 98% of the water needed for crop irrigation – {concentrated in the bootheel}

MISSOURI WATER RESOURCES PLAN

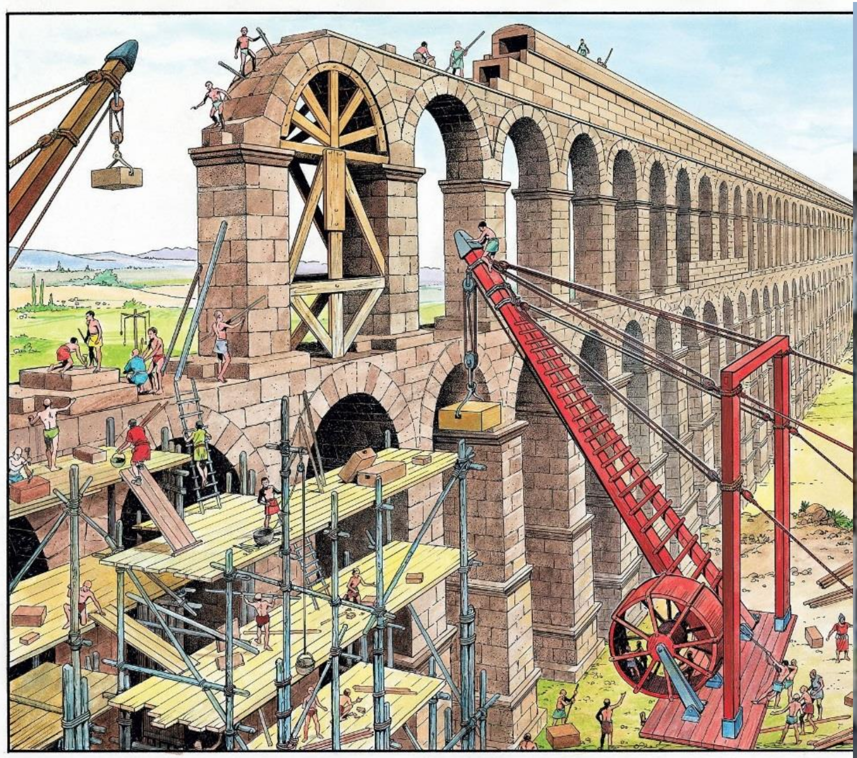
Conclusions

- Plentiful precipitation limits irrigation to about 20% of grain acres statewide
  - In the bootheel region, producers irrigate as much as 75% of crop acres
- Missouri holds vast groundwater supplies especially south of Missouri River
  - Based on agriculture uses, several hundreds of years supply available in aquifers
- Yet stakeholders remain focused on stewardship and efficient water use

MISSOURI WATER RESOURCES PLAN

For the Future, We Can Study the Past

- Technology allows us to overcome obstacles likely encountered in the future
- Technology enables us to work smarter as we solve problems

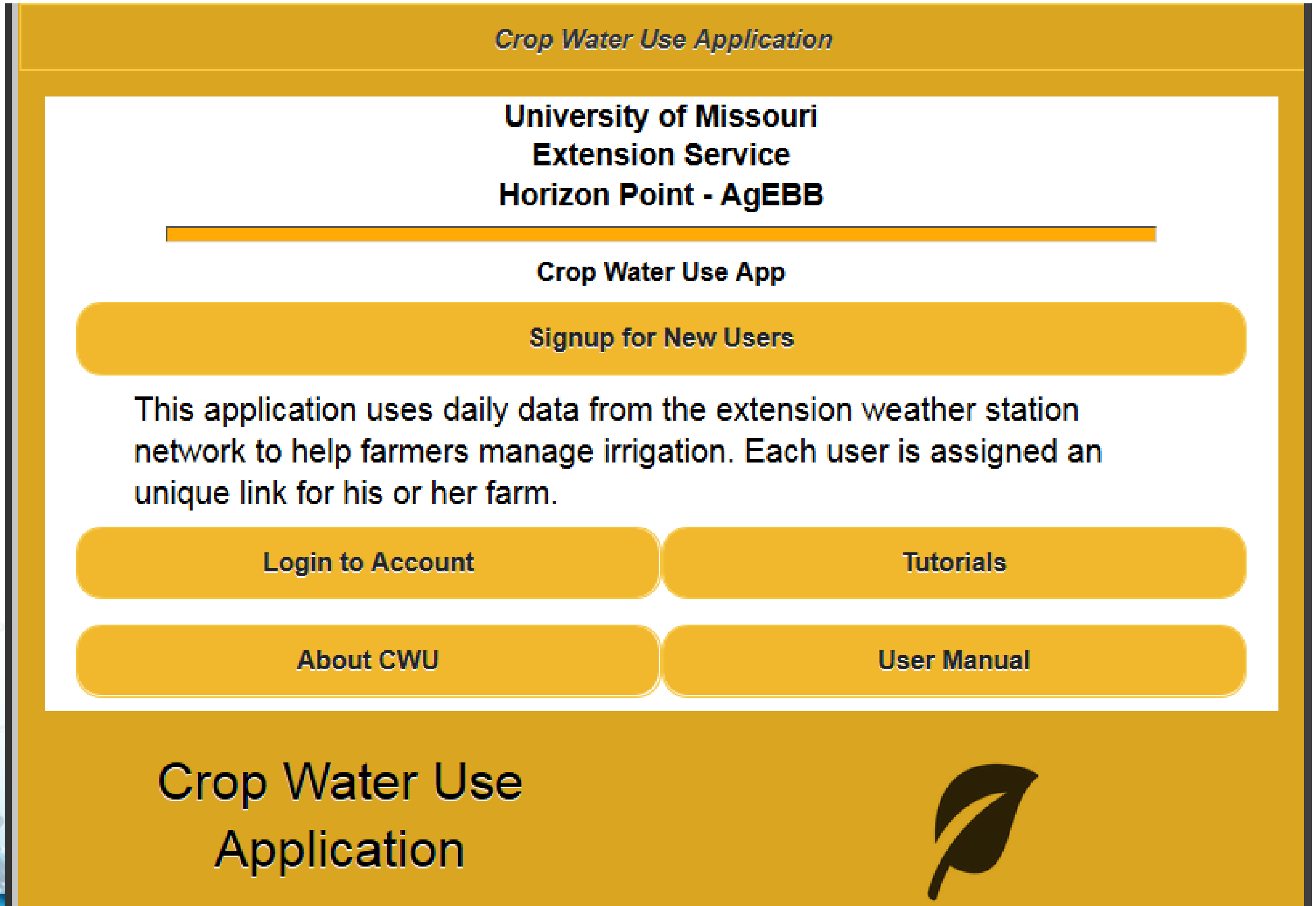


The Future

- New technologies may bring field drainage and irrigation to new sites

The Future

- Smart phone apps and computer programs help producers manage water use



Agricultural Needs Discussion

Water Quality Analysis and Results

Water Quality Task Summary

Goals

- Recognize water quality and assess how this affects water supply uses

Elements

- Analyze statewide water quality and the impact on consumptive water supplies
- Evaluate water quality for assessment of wastewater improvements

Considerations

- Not intended as a regulatory plan
- Water quality regulations are authorized under different regulatory statutes than those that authorize the development of the statewide water resources plan

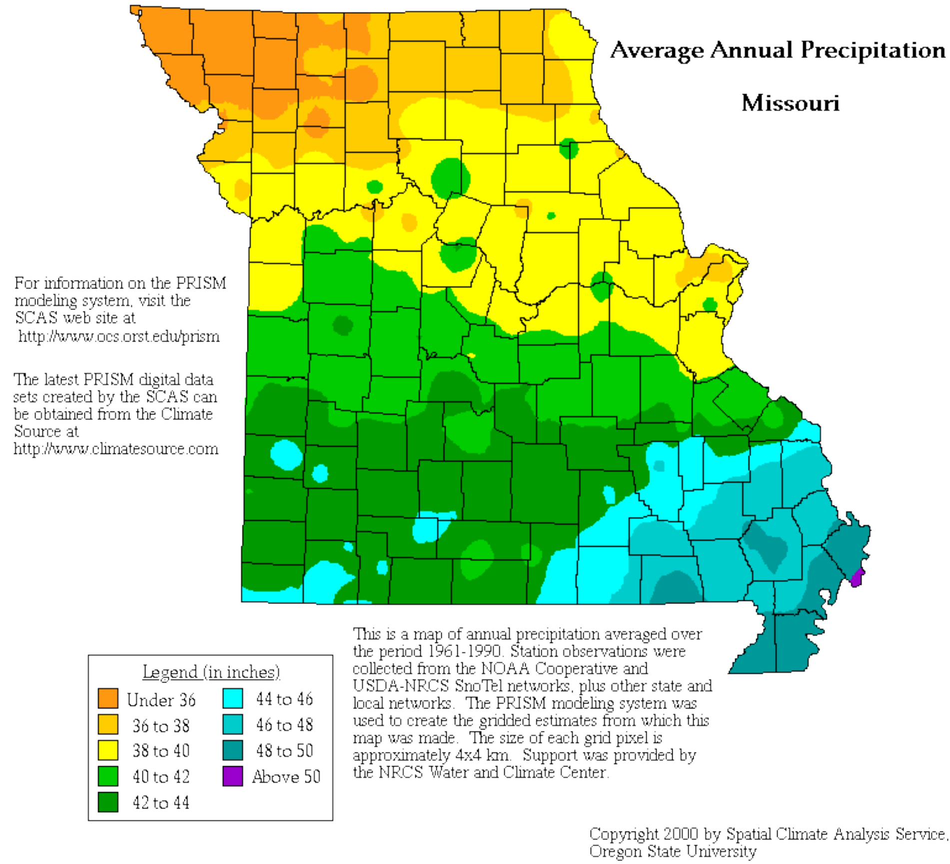
Water Quality Methodology Overview

- Data Compilation
- Summarize Current Statewide Water Quality
- Assess Spatial Trends and Identify Regional Areas of Concern
- Assess Trends in Water Quality Over Time
- Additional Water Quality Discussion
- Develop Water Quality Report

MISSOURI WATER RESOURCES PLAN

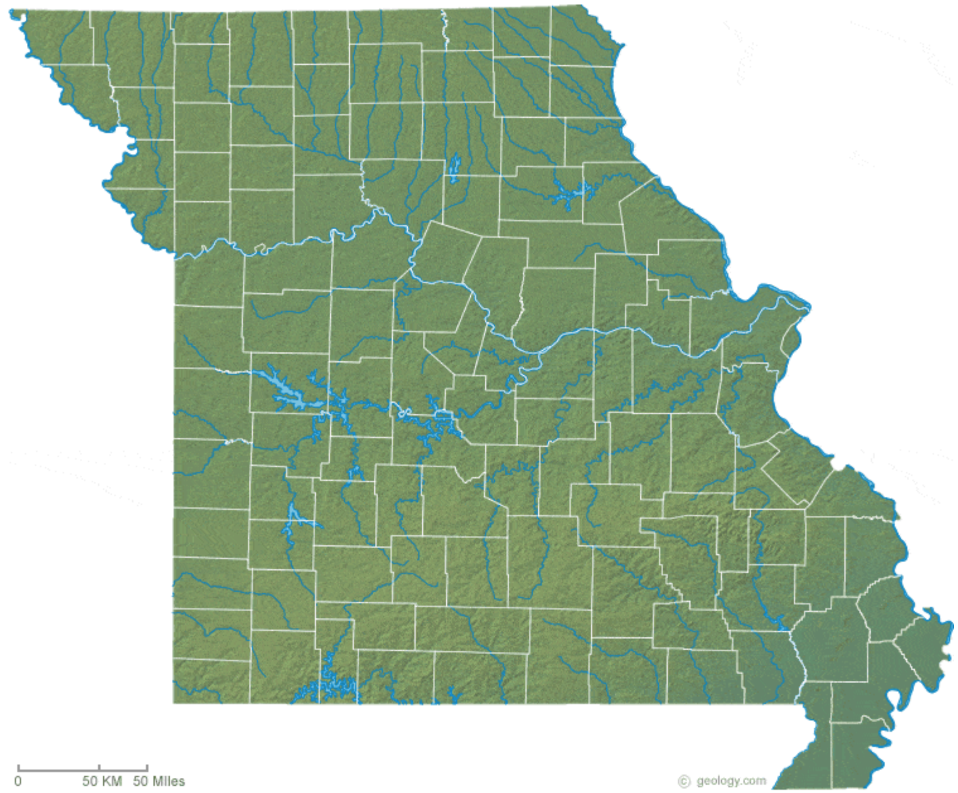
Setting and Climate

- High-level, statewide climate description and discussion
- Precipitation patterns
- Seasonal patterns
- Average annual runoff

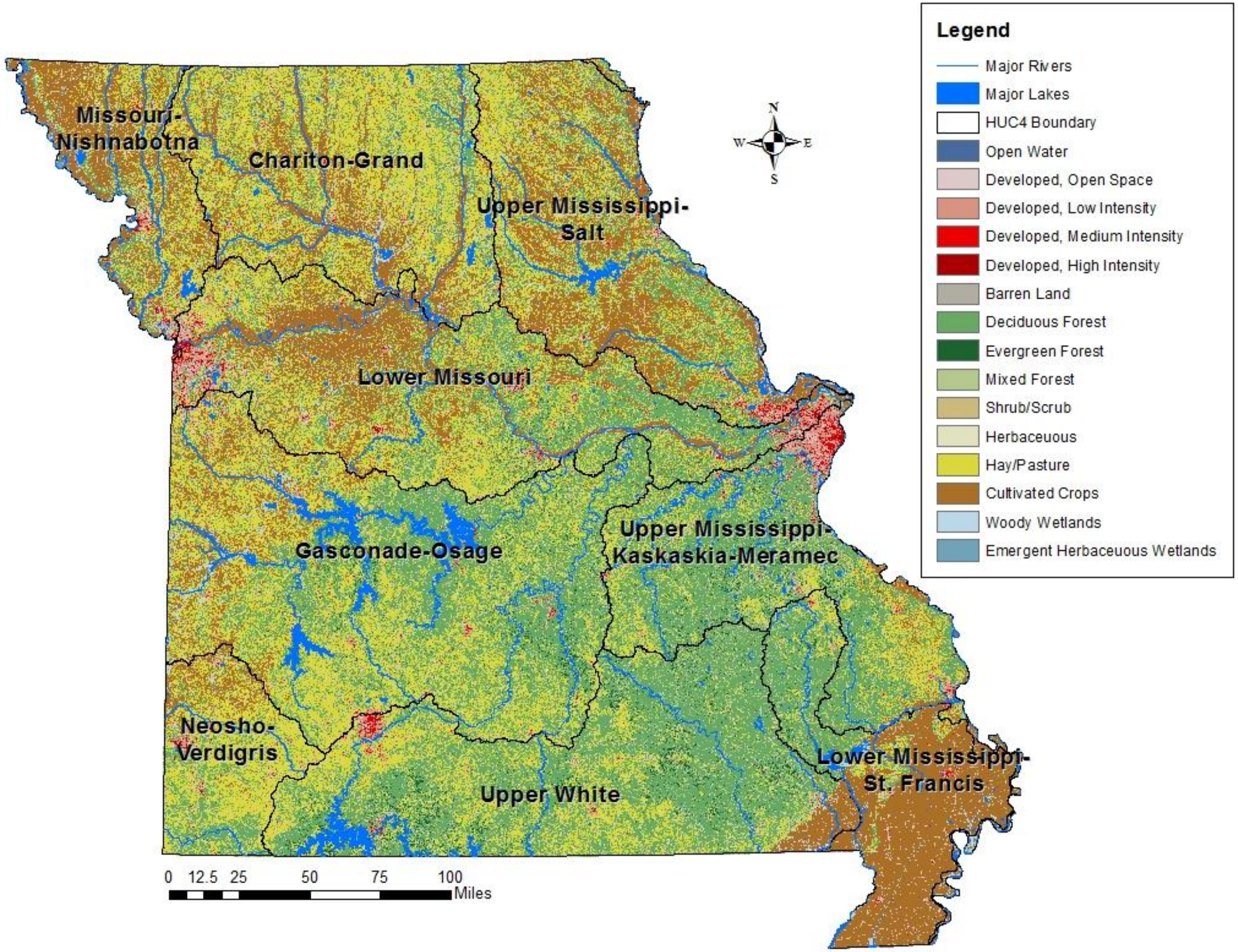


Physiography

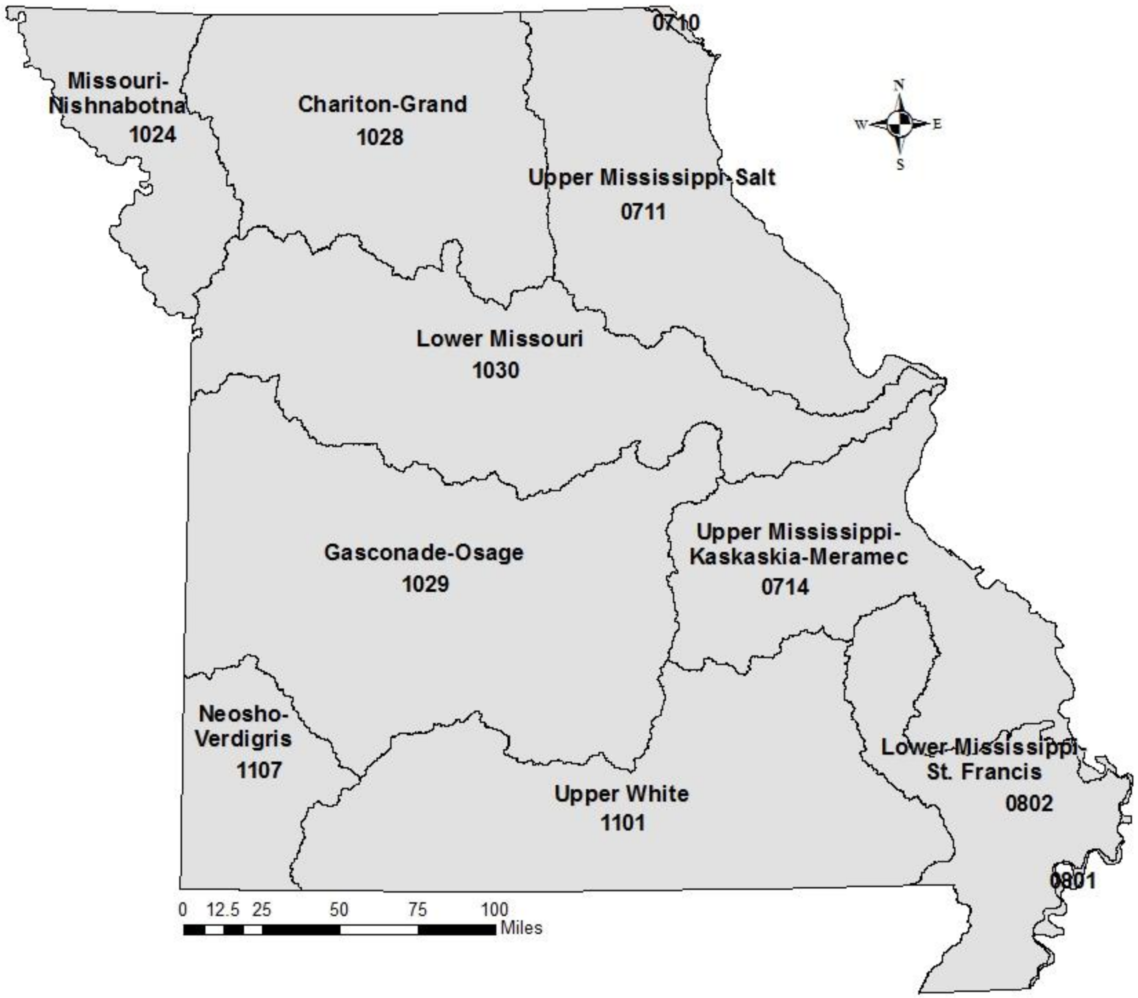
- Major watersheds
- Land use types
- Topography
- Geological formations
- Groundwater provinces



Land Cover


Missouri-
Nishnabotna
Chariton-Grand
Upper Mississippi-
Salt
Lower Missouri
Gasconade-Osage
Upper Mississippi-
Kaskaskia-Meramec
Neosho-
Verdigris
Upper White
Lower Mississippi-
St. Francis
N
S
W
E
0 12.5 25 50 75 100
Miles
Legend
Major Rivers
Major Lakes
HUC4 Boundary
Open Water
Developed, Open Space
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Barren Land
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub/Scrub
Herbaceuous
Hay/Pasture
Cultivated Crops
Woody Wetlands
Emergent Herbaceuous Wetlands

Missouri HUC4 Basin Map



Surface Water Quality Analysis Overview

- Statewide Water Quality Overview
- HUC 4/Major Basins-Level Discussion
- Source WQ Impacts to Treatment Cost
- Temporal Trends – Drinking Water Sources
- Temporal Trends – Recreation

MISSOURI WATER RESOURCES PLAN

Surface Water Quality

General Statewide Discussion

- Primary parameters of concern
- Summary of water quality monitoring in Missouri
  - Monitoring agencies, locations
  - Local studies and additional data sources
  - Volunteer monitoring programs
- Overview of surface waters designated for water supply uses
- Current impairments based on 303(d) list
- Statewide changes in 303(d) listings over time
  - Changes in regulatory focus

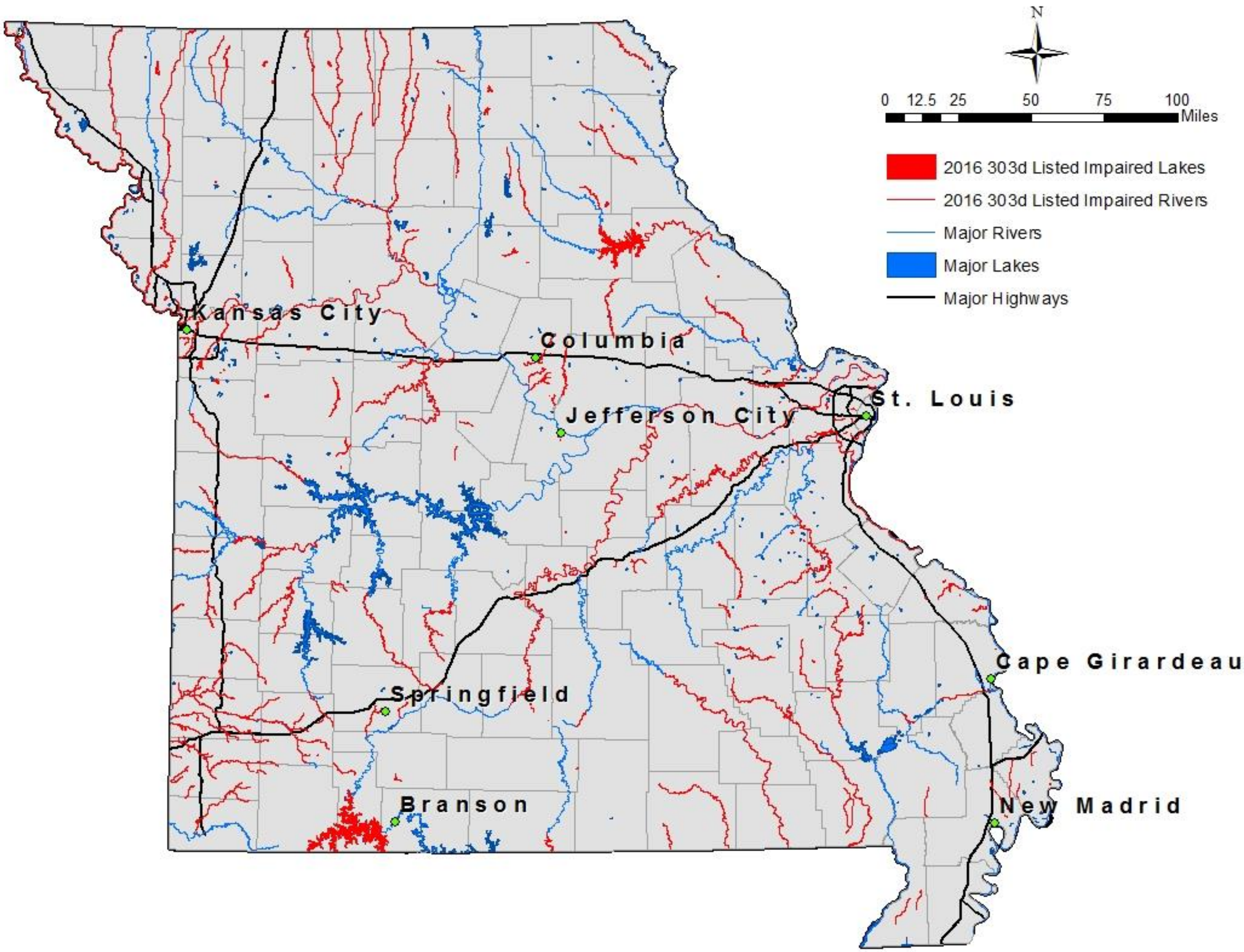
MISSOURI WATER RESOURCES PLAN

Primary Parameters of Concern

Parameter	Primary Sectors Impacted		
	Supply	Wastewater	Recreation and Aesthetics
Ammonia		x	
Bacteria (*E. coli*)	x	x	x
Chloride	x	x	
Low dissolved oxygen (DO)		x	
Metals (cadmium, copper, lead, manganese, nickel, zinc)	x	x	
Nitrates (primarily groundwater)	x		
Nutrients (nitrogen, phosphorus)	x	x	x
Total organic carbon (TOC)	x		
Pesticides (atrazine, others)	x		
Radiologicals (gross alpha)	x		
Sulfates		x	
Total suspended solids (TSS)	x	x	x

MISSOURI WATER RESOURCES PLAN

MoDNR 2016 303(d) Listed Impaired Waters



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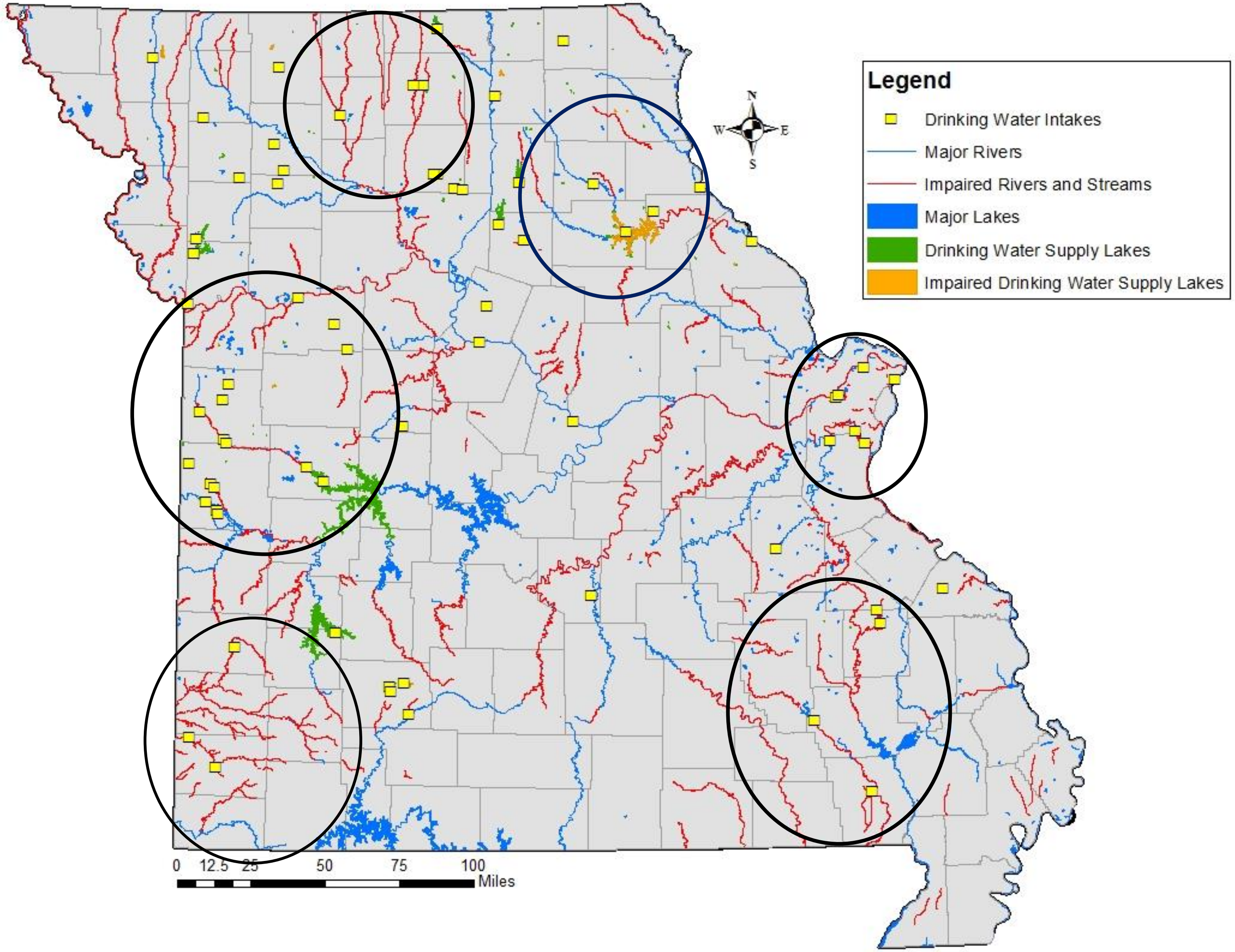
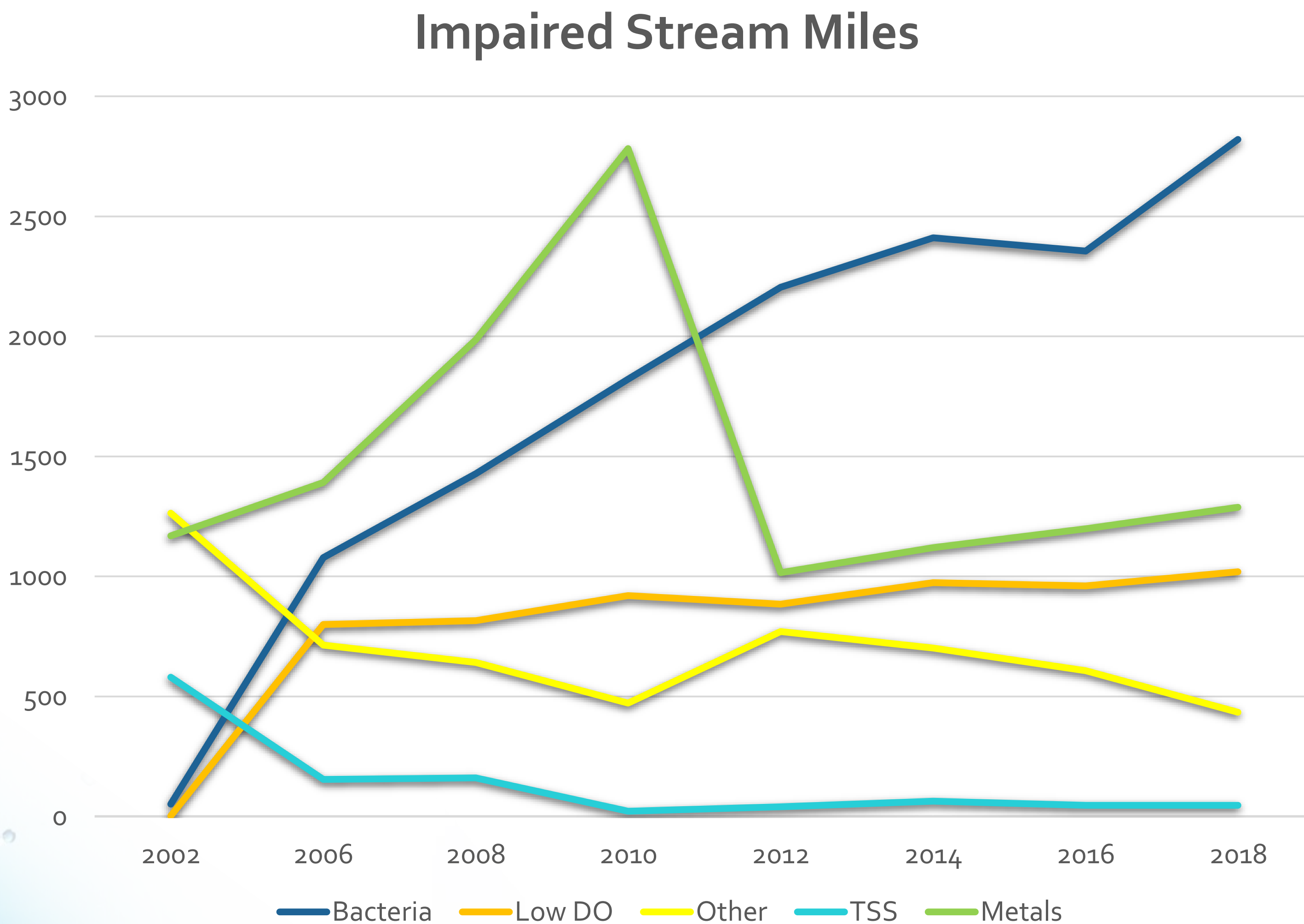
Impacts to Public Drinking Water Supplies



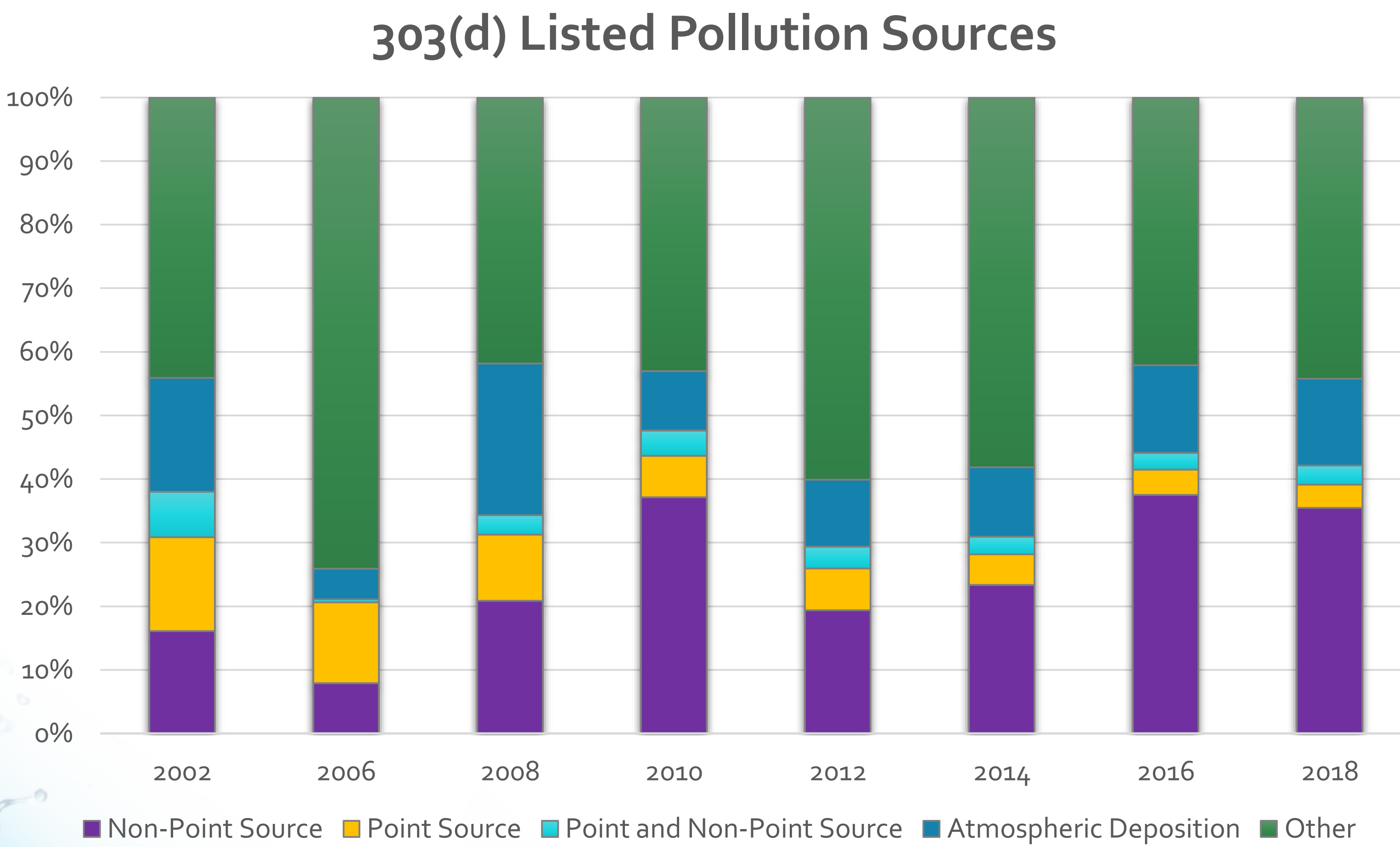
MISSOURI WATER RESOURCES PLAN

Changes to 303(d) Listings: 2002–2018



MISSOURI WATER RESOURCES PLAN

Changes to 303(d) Listings: 2002–2018



** Other field includes agricultural, industrial, toxic waste/superfund, physical modifications, natural, and unknown sources*

Surface Water Quality

HUC4/Major Basins-Level Discussion

- Spatial and temporal variability
  - Sources
  - Parameters
  - Uses
- Area-specific issues
- Sources of water quality concerns
- Focus on potential impacts to drinking water supplies

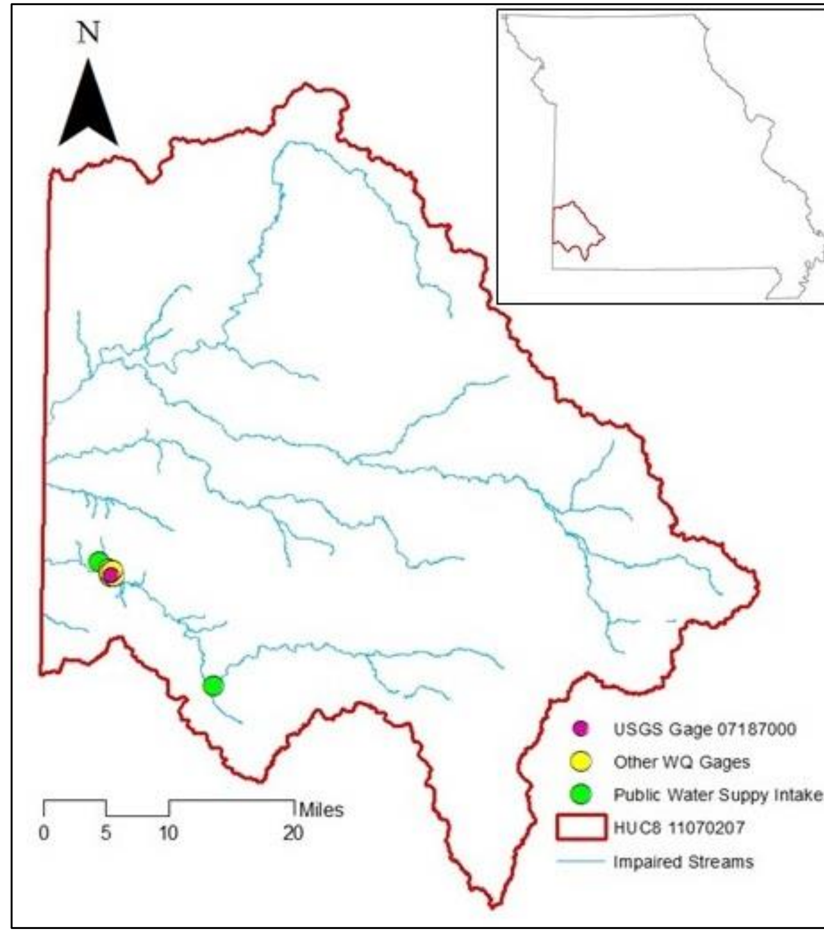
Surface Water Quality

Temporal Trend Analysis

- Focus on impacts to water supply
- Methodology
  - Account for impacts of variable flow in rivers and streams
    - Linear regression to isolate flow influence
    - Flow-weighted concentrations
  - Account for impacts of seasonal variability
    - Kendall test for seasonality
- Data limitations
  - Need long periods of record
  - Regular and consistent sampling regime
  - Co-located flow and water quality data

Temporal Trend Analysis

- Pilot site - Shoal Creek
- Public drinking water supply
- Impaired for:
  - Metals (cadmium, lead, zinc)
  - Bacteria
  - Nutrients
  - Dissolved oxygen
- Multiple data sources:
  - MoDNR
  - NCHD
  - EPA
  - USGS (gage 07187000)
- Consecutive monthly data available from January 2009–December 2017



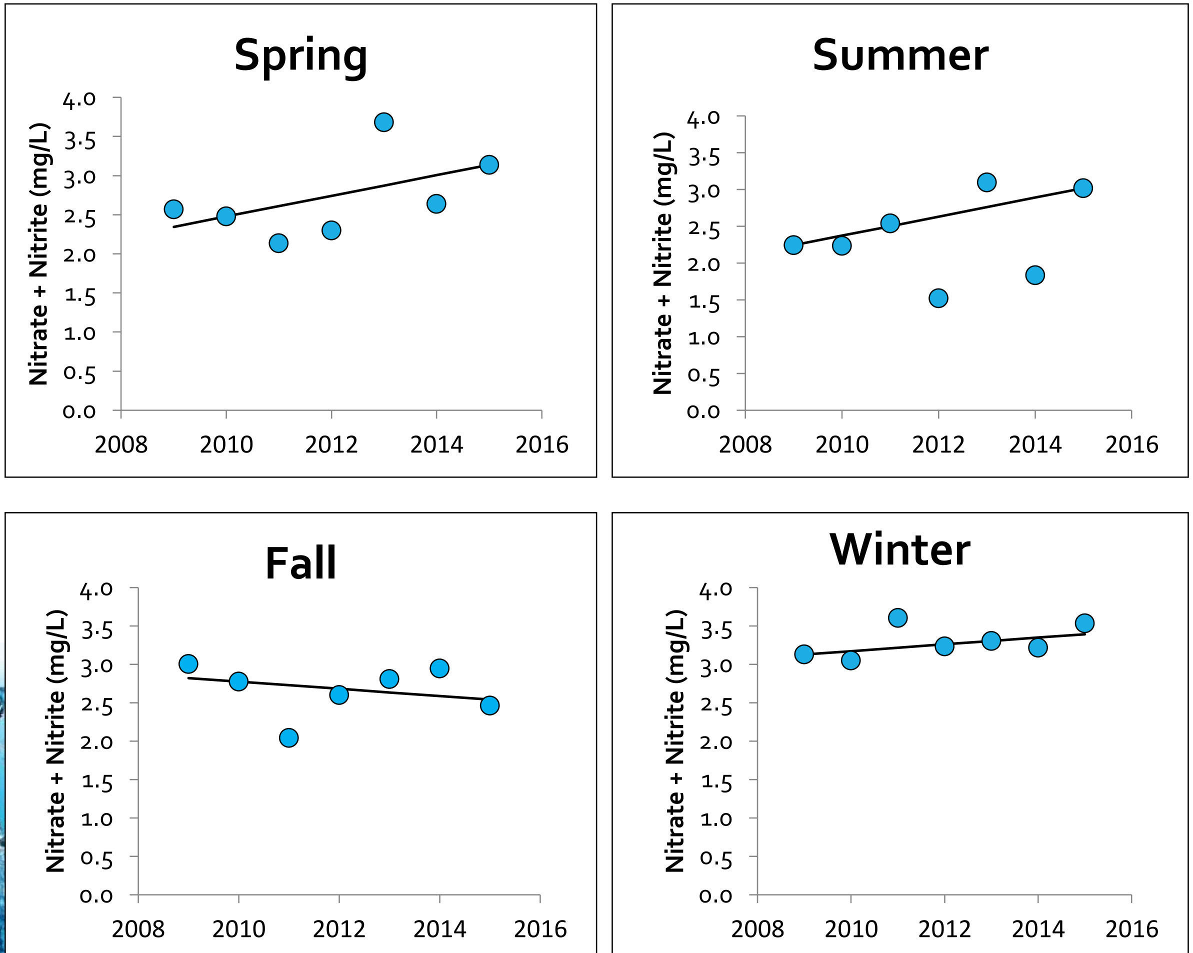
MISSOURI WATER RESOURCES PLAN

Temporal Trend Analysis

- Influence of flow variability on water quality data
  - Linear regression analyses to determine which parameters are influenced by flow
  - Concentrations standardized to flow using equations based on the regressions
    - Flow-influenced parameters adjusted by subtracting the flow-based concentrations
  - Flow-adjusted concentrations can then be analyzed for seasonality
- Seasonality
  - Seasonal Kendall test
    - Provides a measure of change over time independent of seasonal effects
    - Conducts a trend test within each season, then combines to form one overall test
    - Nonparametric
    - Detects monotonic and linear trends

MISSOURI WATER RESOURCES PLAN

Shoal Creek Temporal Trend Analysis



Mann-Kendall trend test	
Kendall's tau	0,810
S	8327,000
p-value	< 0,0001
alpha	0,05

Seasonal Kendall tests identify long-term trends for parameters that vary seasonally

Source Water Quality and Impacts to Drinking Water Treatment Cost

- The quality of source waters can drive infrastructure
  - Treatment processes
  - Treatment costs
  - Potential Source Changes
- Current issues with drinking water treatment
  - Geographic relationships
  - Trends and future impacts
- Ties into infrastructure discussion

MISSOURI WATER RESOURCES PLAN

Relative Water Quality Drivers/Thresholds by Treatment Type

Treatment Type	Drivers/Thresholds for Treatment						
	Pathogens	TOC	Suspended Solids and Turbidity	Salinity	Hardness	Nutrients/Taste and Odor	Emerging Contaminants
Direct Filtration[1]	LOW	LOW	LOW	LOW	LOW	LOW	LOW
Conventional[1]	MED	MED	MED	LOW	LOW	LOW	LOW
Conventional + Enhanced Coagulation	MED	MED-HIGH	MED-HIGH	LOW	LOW	LOW	LOW
Conventional + Lime Softening	MED	MED-HIGH	MED-HIGH	LOW	HIGH	LOW	LOW
Conventional + Ozone/UV	MED-HIGH	MED-HIGH	MED-HIGH	LOW	LOW	MED-HIGH	MED-HIGH
Conventional + GAC	MED	MED-HIGH	MED-HIGH	LOW	LOW	MED-HIGH	MED-HIGH
Conventional + Membranes	MED-HIGH	MED-HIGH	MED-HIGH	LOW	LOW	LOW	LOW
Conventional + Nanofiltration/Reverse Osmosis	MED-HIGH	MED-HIGH	MED-HIGH	MED-HIGH	MED-HIGH	MED-HIGH	MED-HIGH

UV – Ultraviolet
GAC – Granular Activated Carbon

MISSOURI WATER RESOURCES PLAN

USEPA Drinking Water Secondary Standards

Contaminant	Secondary Maximum Contaminant Level (MCL)	Noticeable Effects Above the Secondary MCL
Aluminum	0.05 to 0.2 milligrams per liter (mg/L)	colored water
Chloride	250 mg/L	salty taste
Color	15 color units	visible tint
Copper	1.0 mg/L	metallic taste; blue-green staining
Corrosivity	Non-corrosive	metallic taste; corroded pipes/ fixtures staining
Fluoride	2.0 mg/L	tooth discoloration
Foaming agents	0.5 mg/L	frothy, cloudy; bitter taste; odor
Iron	0.3 mg/L	rusty color; sediment; metallic taste; reddish or orange staining
Manganese	0.05 mg/L	black to brown color; black staining; bitter metallic taste
Odor	3 threshold odor number (TON)	"rotten-egg", musty, or chemical smell
pH	6.5 - 8.5	low pH: bitter metallic taste; corrosion high pH: slippery feel; soda taste; deposits
Silver	0.1 mg/L	skin discoloration; graying of the white part of the eye
Sulfate	250 mg/L	salty taste
Total dissolved solids (TDS)	500 mg/L	hardness; deposits; colored water; staining; salty taste
Zinc	5 mg/L	metallic taste

Source: USEPA Secondary drinking Water Standards website
https://www.epa.gov/dwstandardsregulations/secondary-drinking-water-standards-guidance-nuisance-chemicals

Treatment Cost Estimates for Varying Source Water Conditions

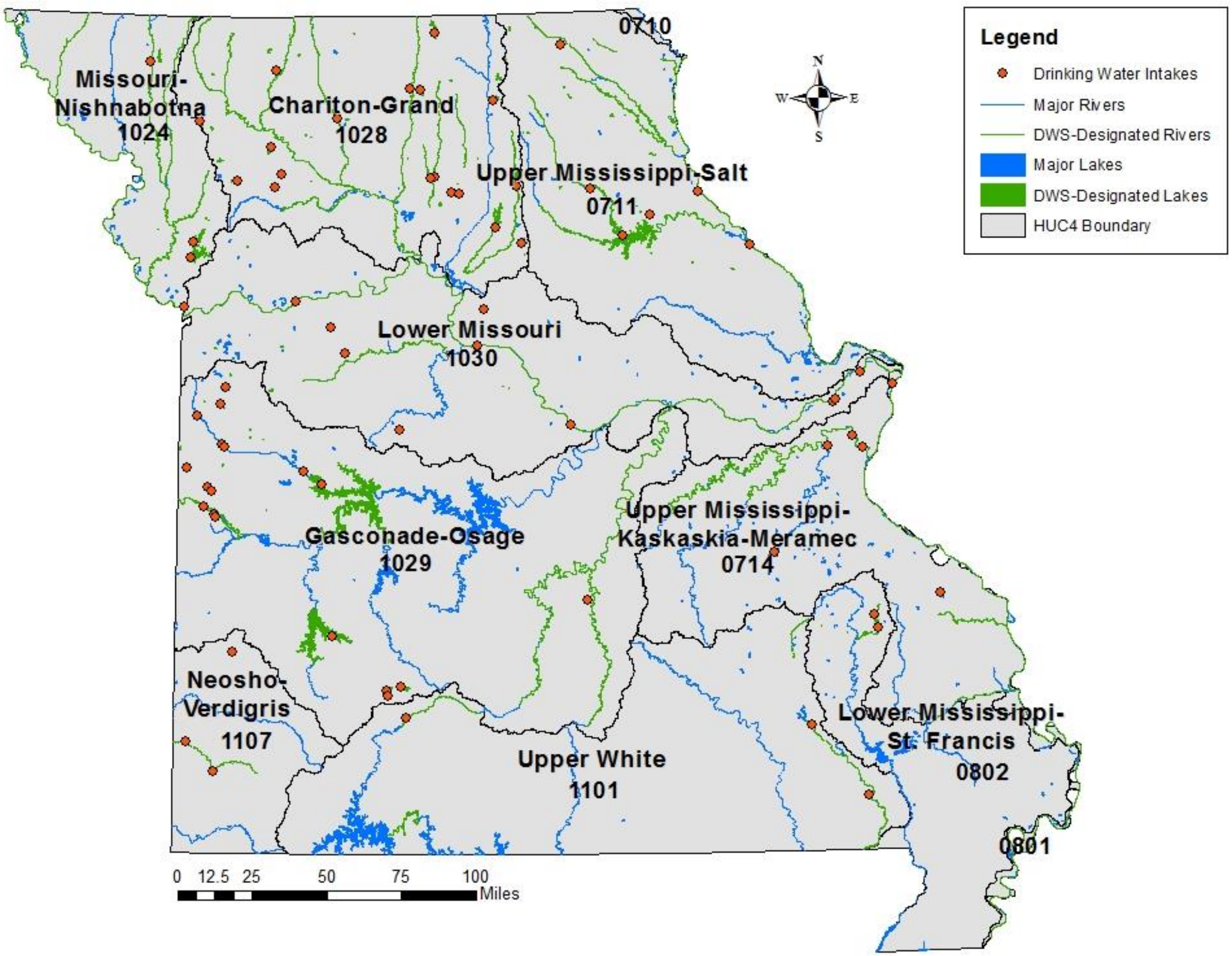
Treatment Type	Source Water Characteristics	Estimated Capital Costs (cost/gpd)
Direct Filtration[1]	Pristine water quality, consistent with few excursions.	$2-3
Conventional[1]	Moderate-high quality water, moderate to high frequency of excursions.	$3-4
Conventional + Enhanced Coagulation	High, natural organic matter (NOM) is precursor material to disinfection by-products (DBPs).	$3-4
Conventional + Lime Softening	High hardness in source water, often accompanied by high NOM, turbidity, and other treatment challenges.	$4-5
Conventional + Ozone/UV	High NOM (precursor to DBPs), high NOM and/or increased levels of pathogens, increased levels of bromide, moderate to severe taste and odor, potential for contaminants of emerging concern (CECs).	$4-5
Conventional + GAC	Similar to Conventional + Ozone/UV, but with lower risk of pathogens in source water.	$3-4
Conventional + Membranes	High pathogens and/or NOM.	$4-5
Conventional + Nanofiltration/Reverse Osmosis	Treats all of the challenging characteristics listed above for NOM removal, disinfection, softening, CECs, and salinity removal. Not always effective for taste and odor issues.	$8-10

UV – Ultraviolet
GAC – Granular Activated Carbon

Aggregated Drinking Water Source Analyses

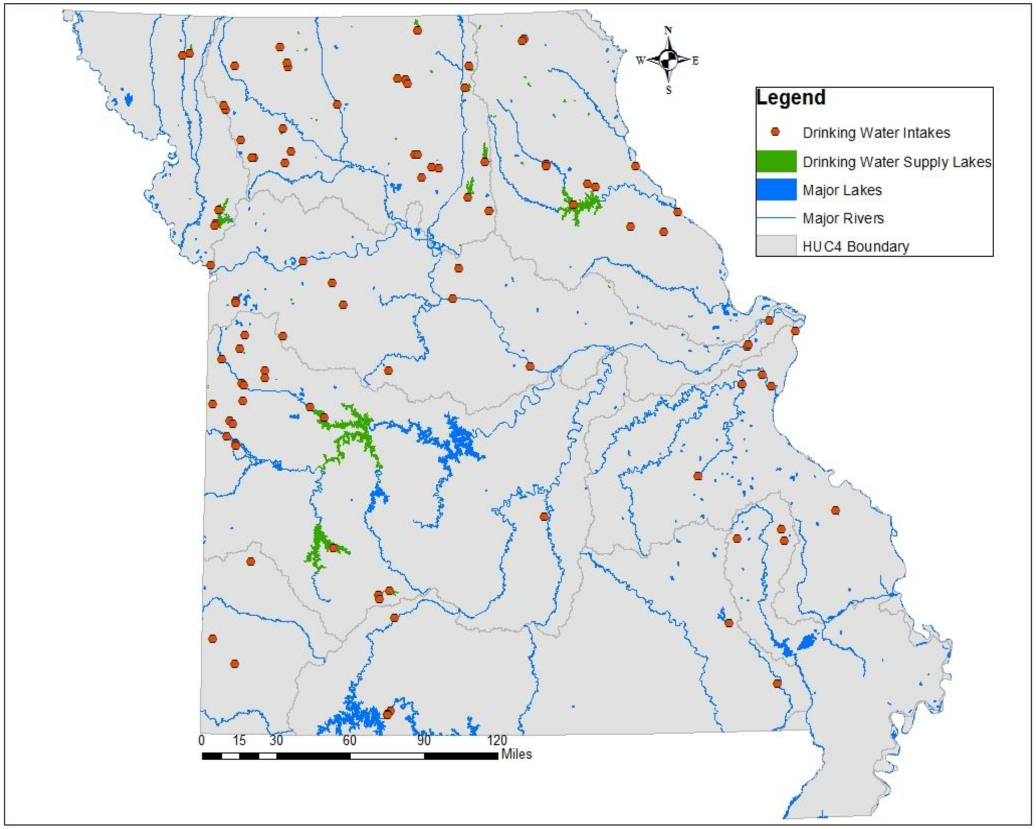
- Drinking water lakes
  - Data from drinking water lakes were aggregated by HUC4 to analyze DWS water quality trends by watershed
- Drinking water rivers
  - Data from drinking water lakes were aggregated by HUC4 to analyze DWS water quality trends by watershed
  - Data from the Missouri River was aggregated and analyzed to evaluate water quality trends for a major DWS river

Drinking Water Source Analysis



MISSOURI WATER RESOURCES PLAN

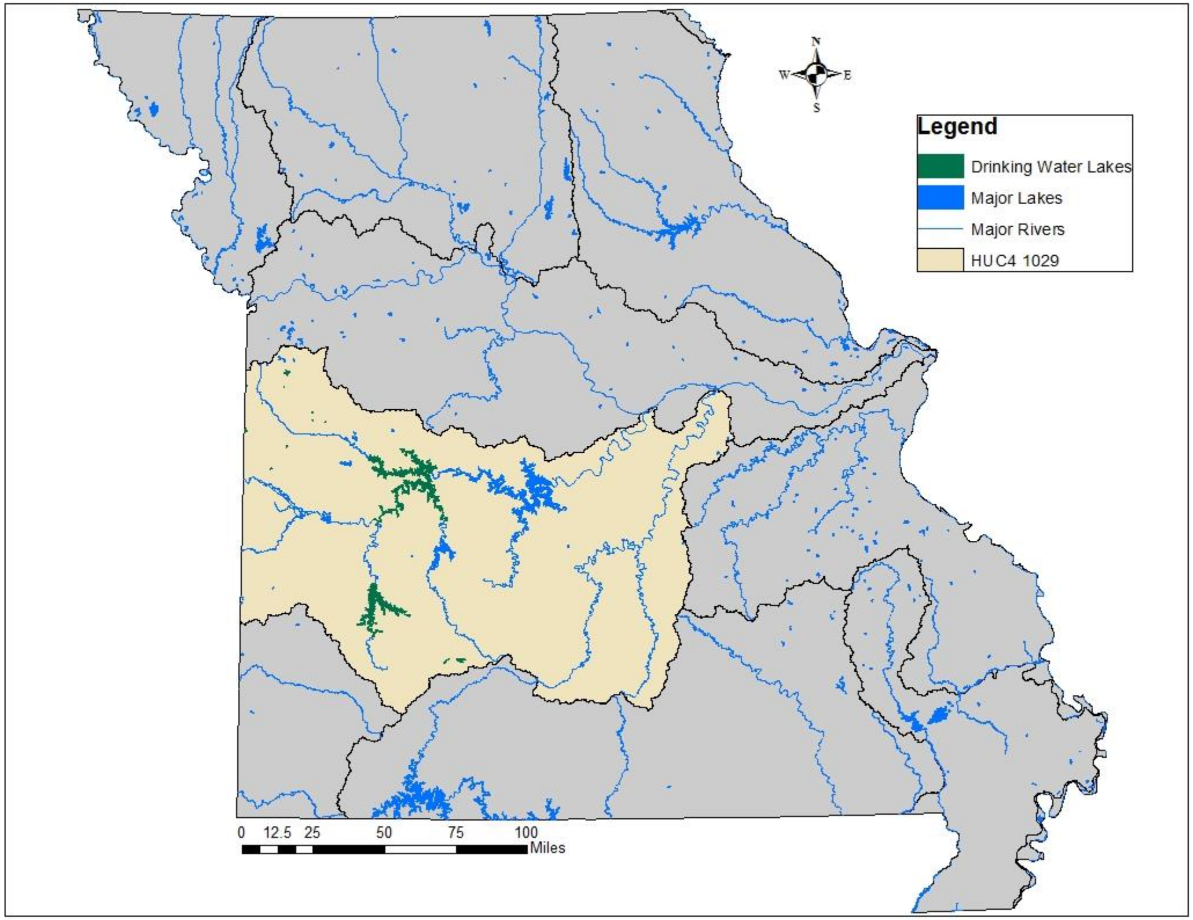
Drinking Water Lakes by HUC4 Basin



HUC4 Basin	Number of Drinking Water Lakes
Upper Mississippi-Salt	9
Upper Mississippi-Kaskaskia-Meramec	0
Missouri-Nishnabotna	4
Chariton-Grand	25
Gasconade-Osage	10
Lower Missouri	7
Upper White	0
Neosho-Verdigris	1
Lower Mississippi-St. Francis	3

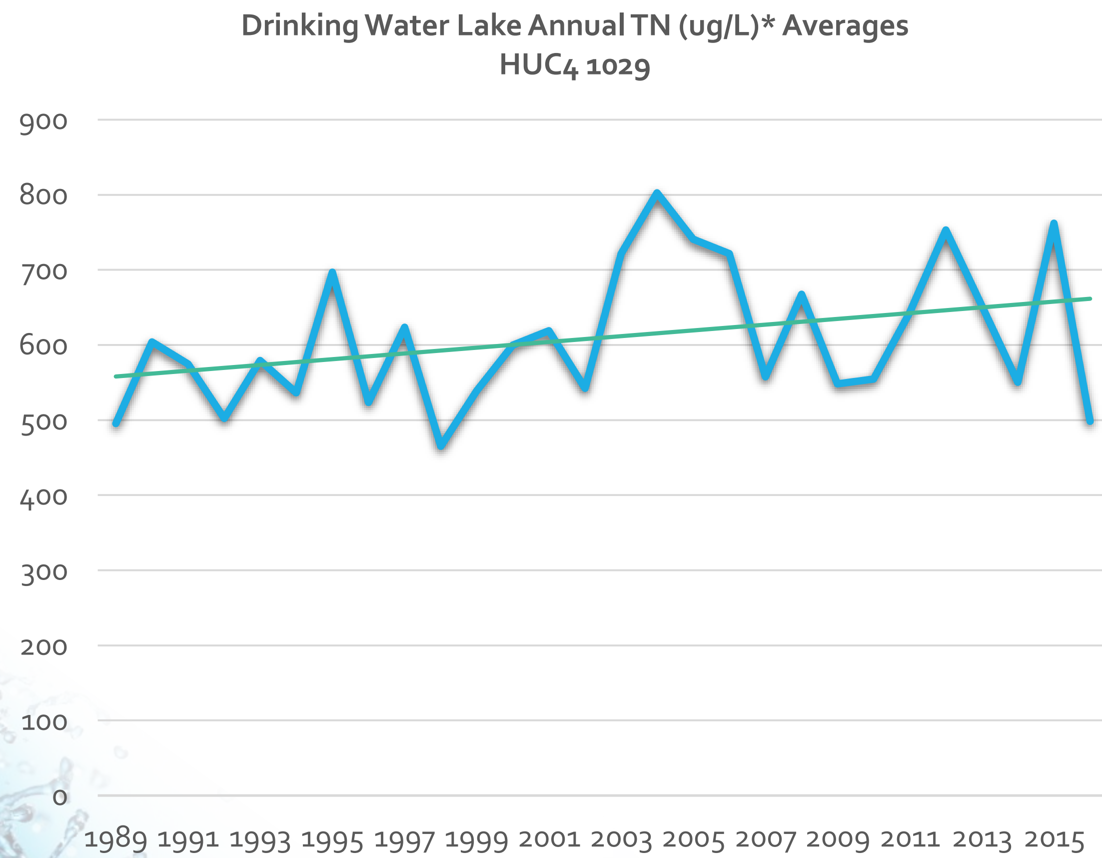
MISSOURI WATER RESOURCES PLAN

Drinking Water Lake Analysis
Gasconade-Osage Basin (HUC4 1029)



Lake Name	Number Stations
Garden City Lake	2
Adrian Reservoir	1
Fellows Lake	1
Stockton Lake	1
North Lake	1
McDaniel Lake	1
Harrisonville City Lake	1
Truman Reservoir	2
Butler Lake	1

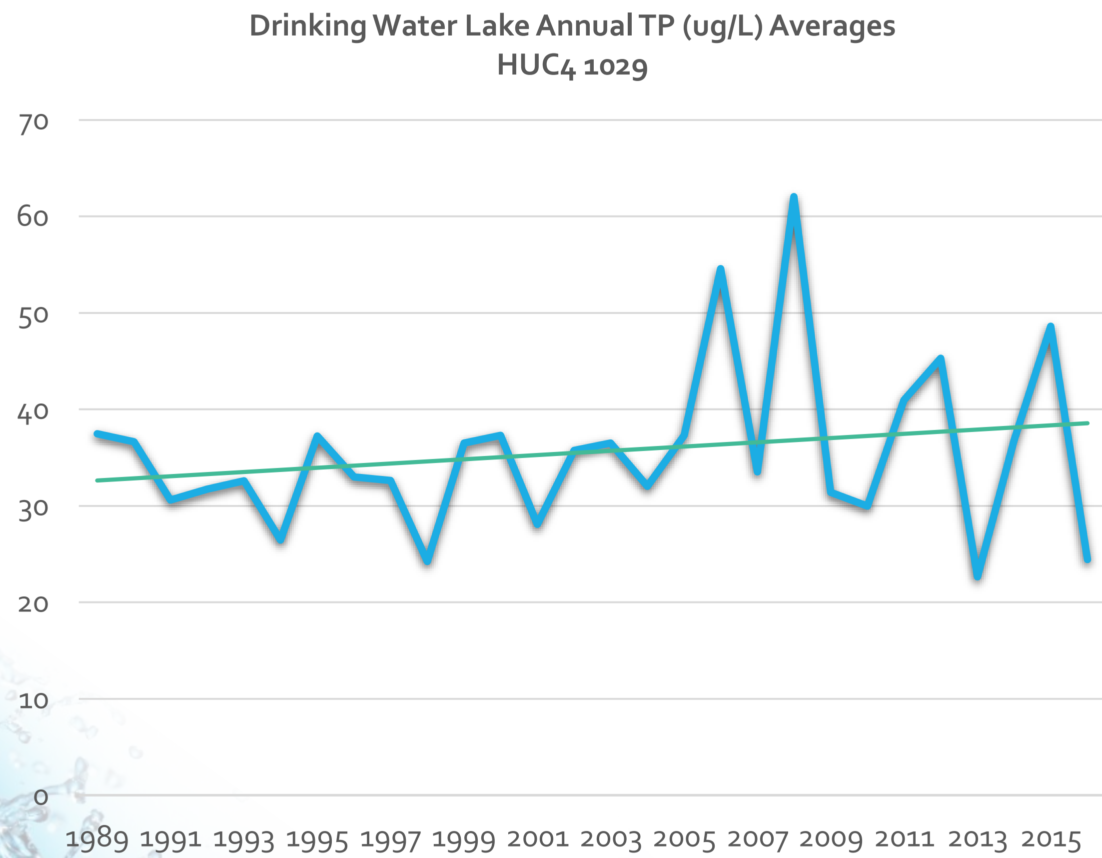
Drinking Water Lake Total Nitrogen Analysis Gasconade-Osage Basin (HUC4 1029)



*micrograms per liter

Lake Name	Number Samples
Garden City Lake	12
Adrian Reservoir	12
Fellows Lake	188
Stockton Lake	627
North Lake	102
McDaniel Lake	114
Harrisonville City Lake	37
Truman Reservoir	12
Butler Lake	48

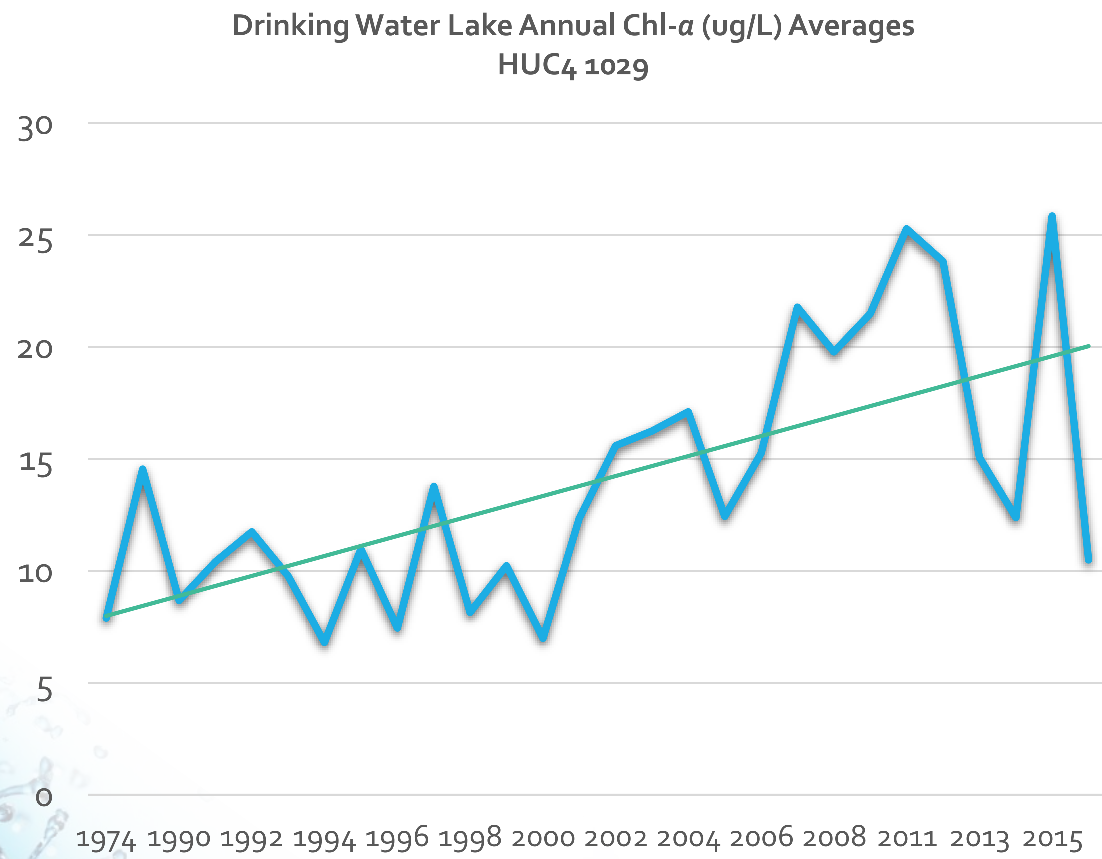
Drinking Water Lake Total Phosphorus Analysis Gasconade-Osage Basin (HUC4 1029)



*micrograms per liter

Lake Name	Number Samples
Garden City Lake	12
Adrian Reservoir	12
Fellows Lake	542
Stockton Lake	656
North Lake	102
McDaniel Lake	457
Harrisonville City Lake	37
Truman Reservoir	12
Butler Lake	48

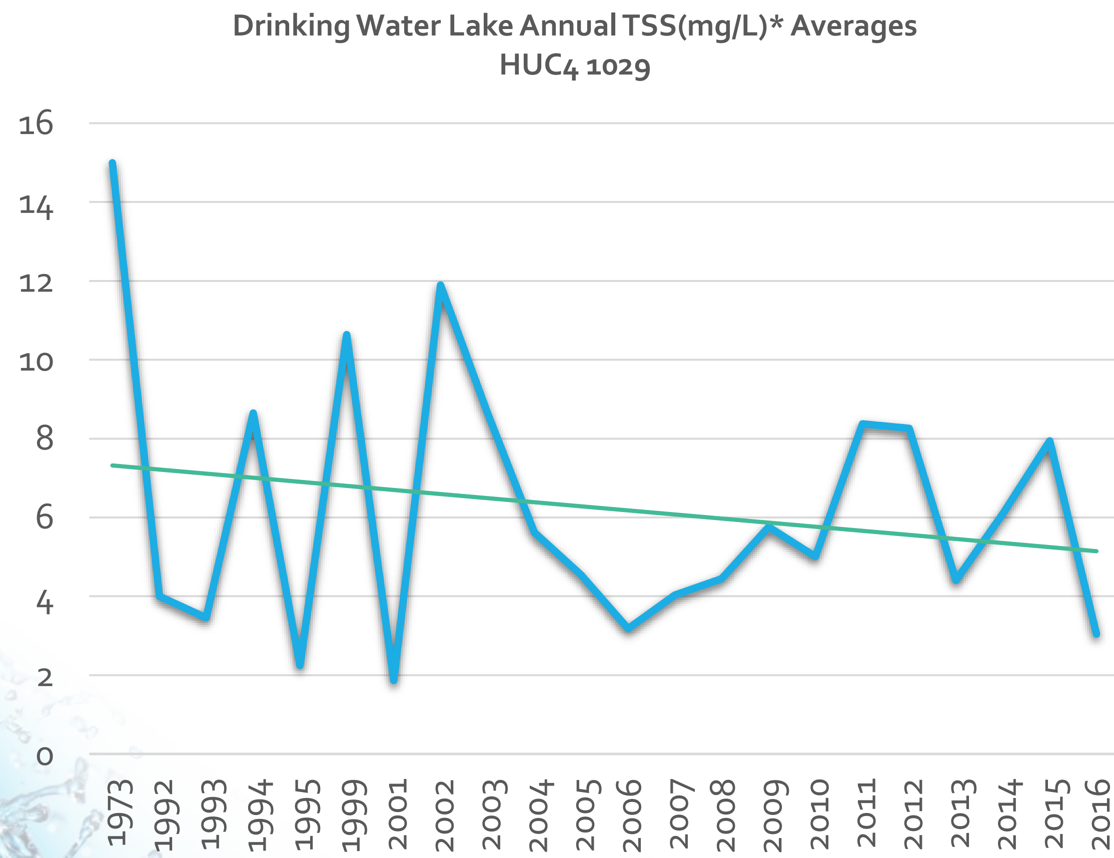
Drinking Water Lake Chlorophyll-*a* Analysis Gasconade-Osage Basin (HUC4 1029)



**micrograms per liter*

Lake Name	Number Samples
Garden City Lake	12
Adrian Reservoir	12
Fellows Lake	165
Stockton Lake	179
North Lake	44
McDaniel Lake	212
Harrisonville City Lake	12
Truman Reservoir	0
Butler Lake	16

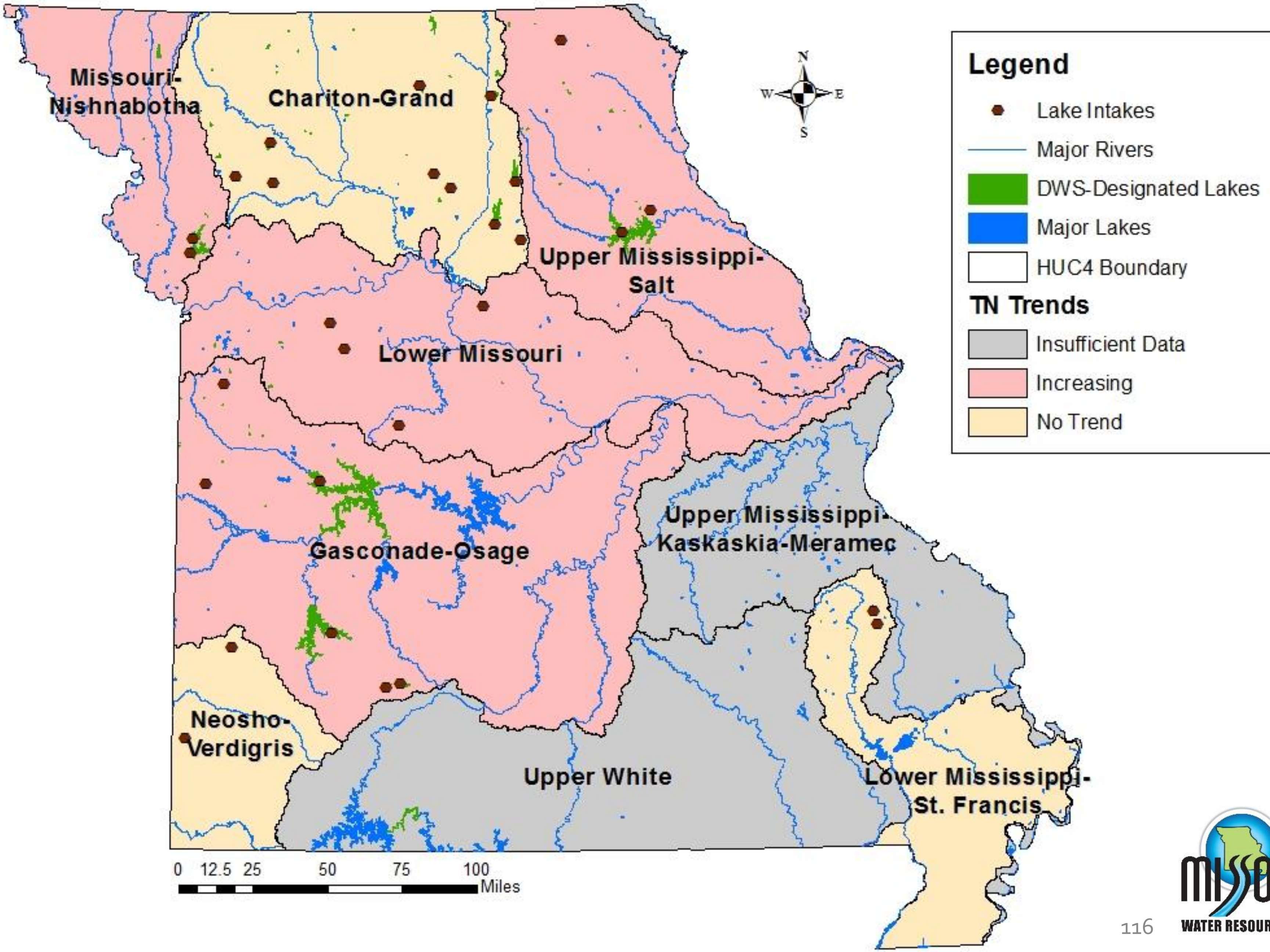
Drinking Water Lake Total Suspended Solid Analysis Gasconade-Osage Basin (HUC4 1029)



*micrograms per liter

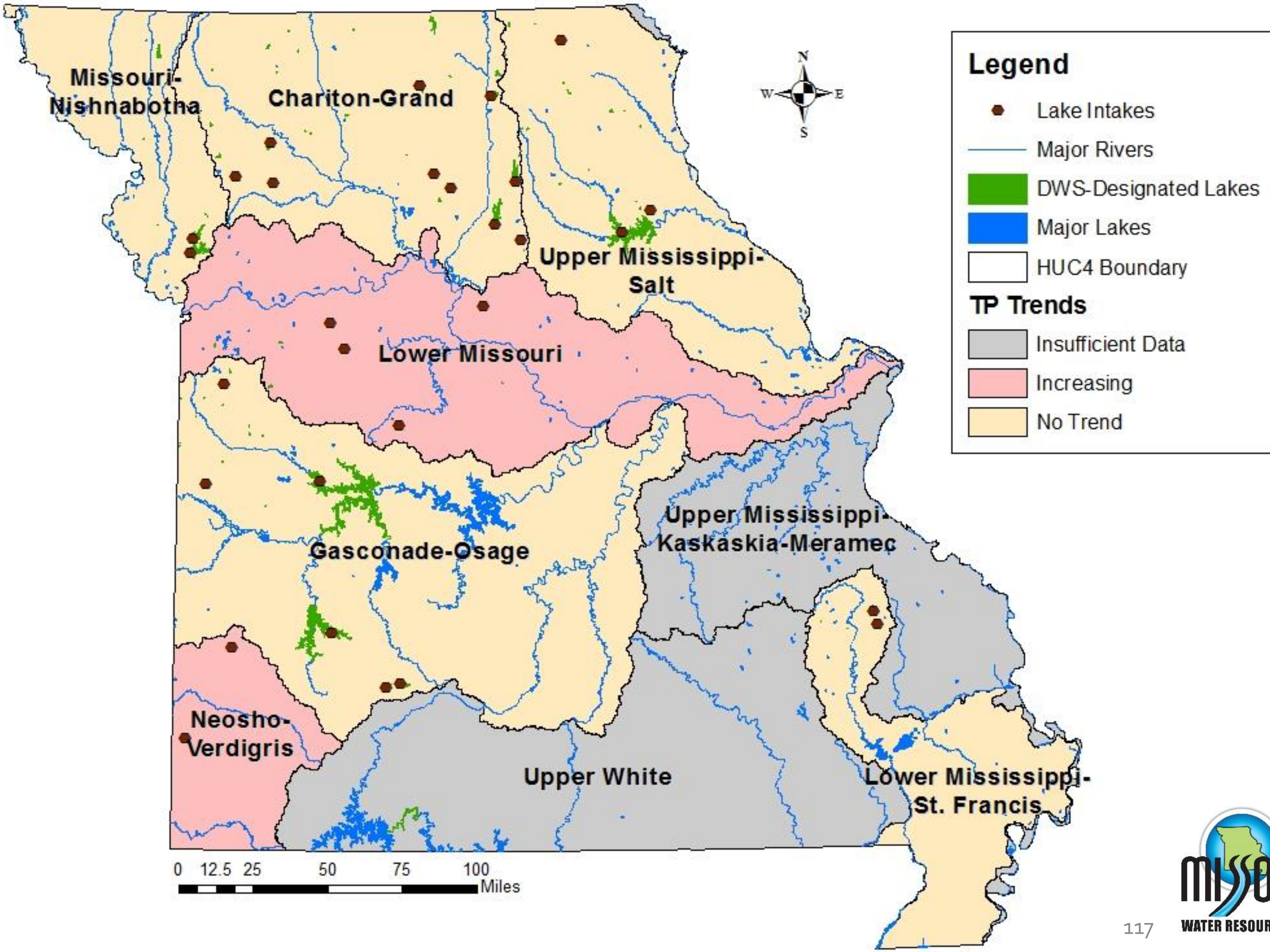
Lake Name	Number Samples
Garden City Lake	0
Adrian Reservoir	0
Fellows Lake	71
Stockton Lake	462
North Lake	18
McDaniel Lake	108
Harrisonville City Lake	3
Truman Reservoir	0
Butler Lake	31

Annual Total Nitrogen Trends
HUC4 Basin Drinking Water Lakes



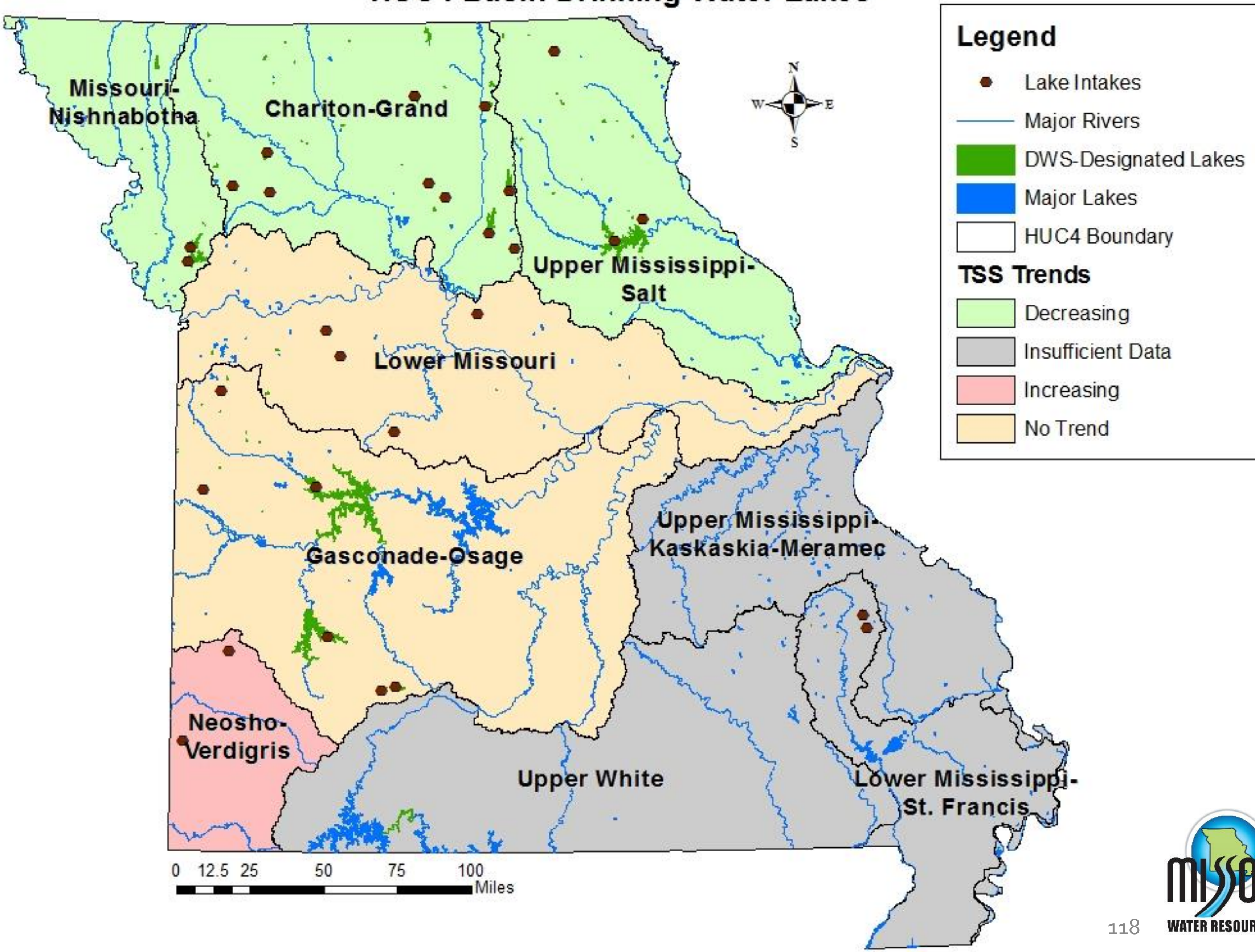
MISSOURI WATER RESOURCES PLAN

Annual Total Phosphorus Trends
HUC4 Basin Drinking Water Lakes

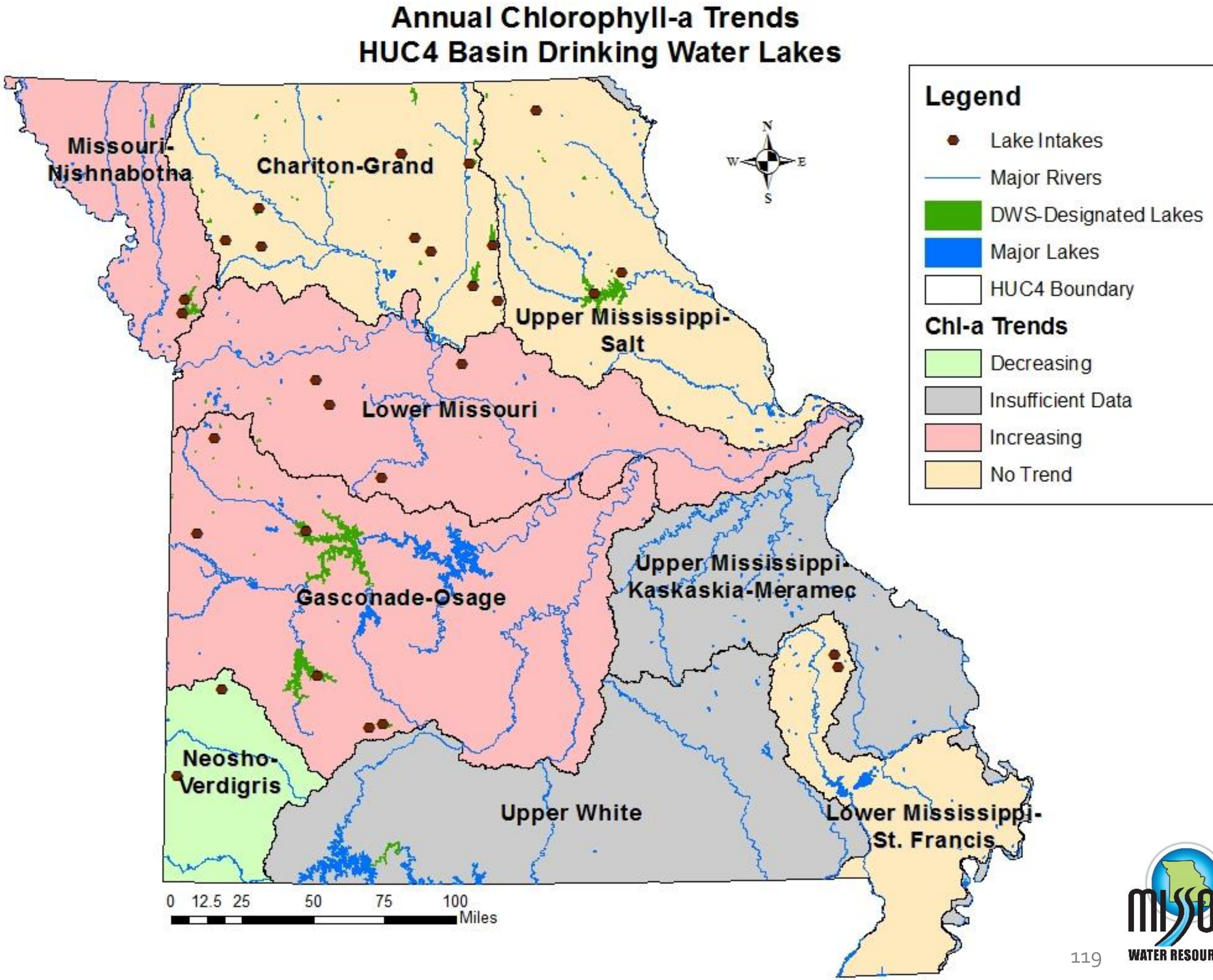


MISSOURI WATER RESOURCES PLAN

Annual Total Suspended Solid Trends
HUC4 Basin Drinking Water Lakes

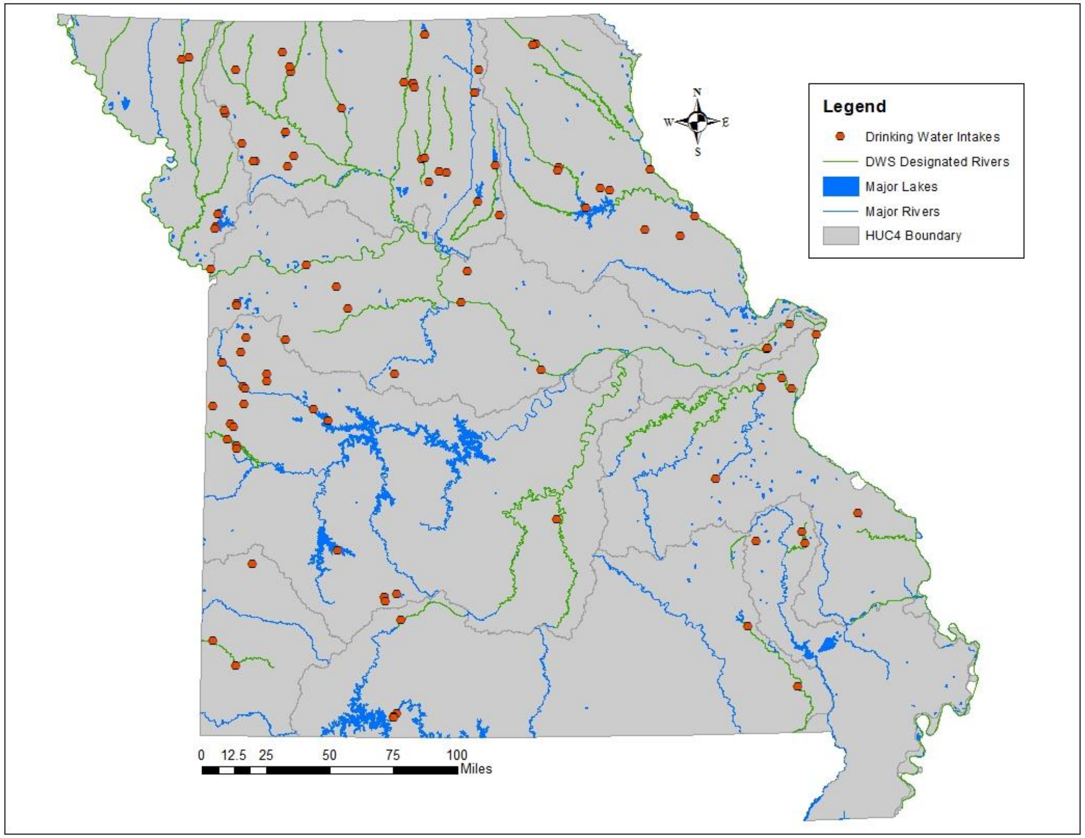


MISSOURI WATER RESOURCES PLAN



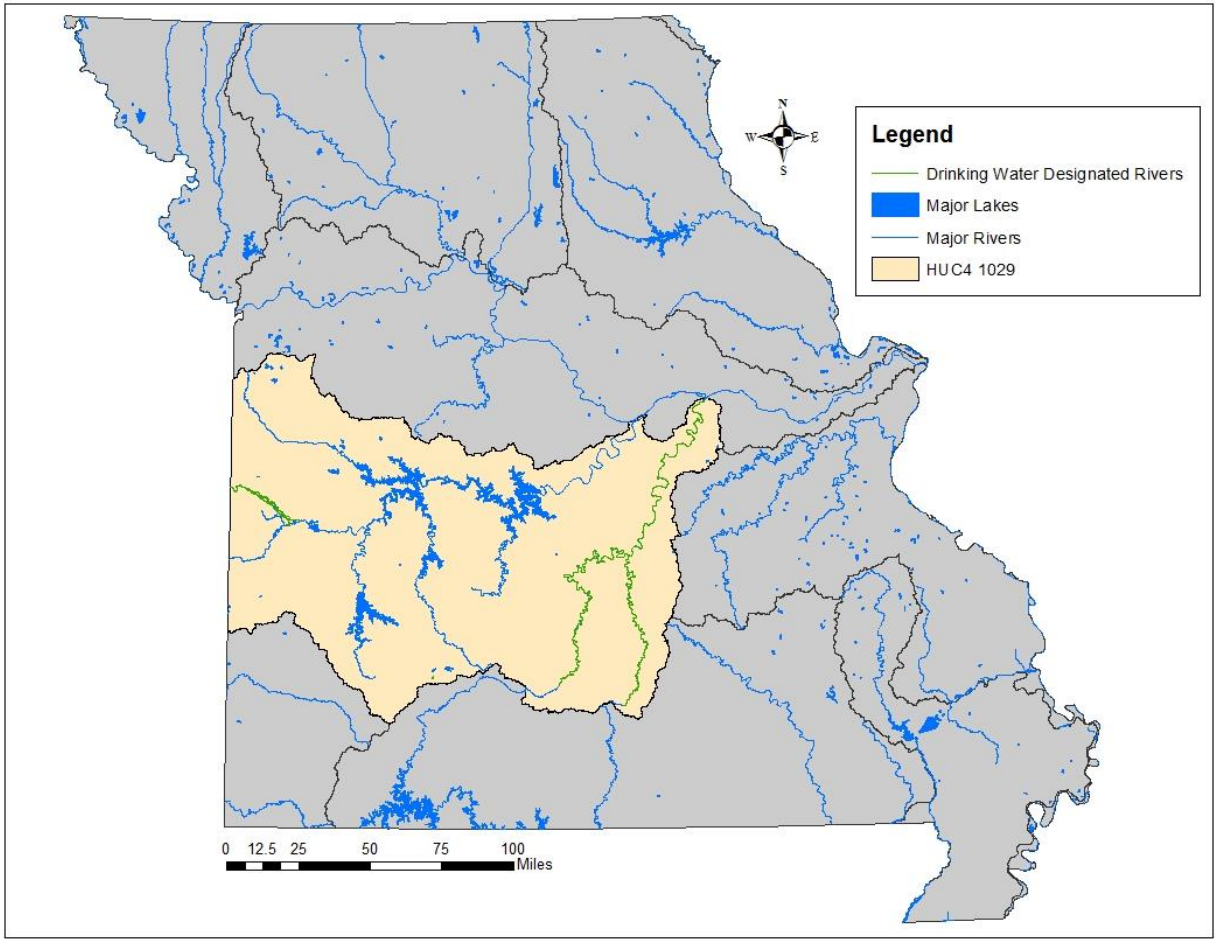
MISSOURI WATER RESOURCES PLAN

Drinking Water Rivers by HUC4



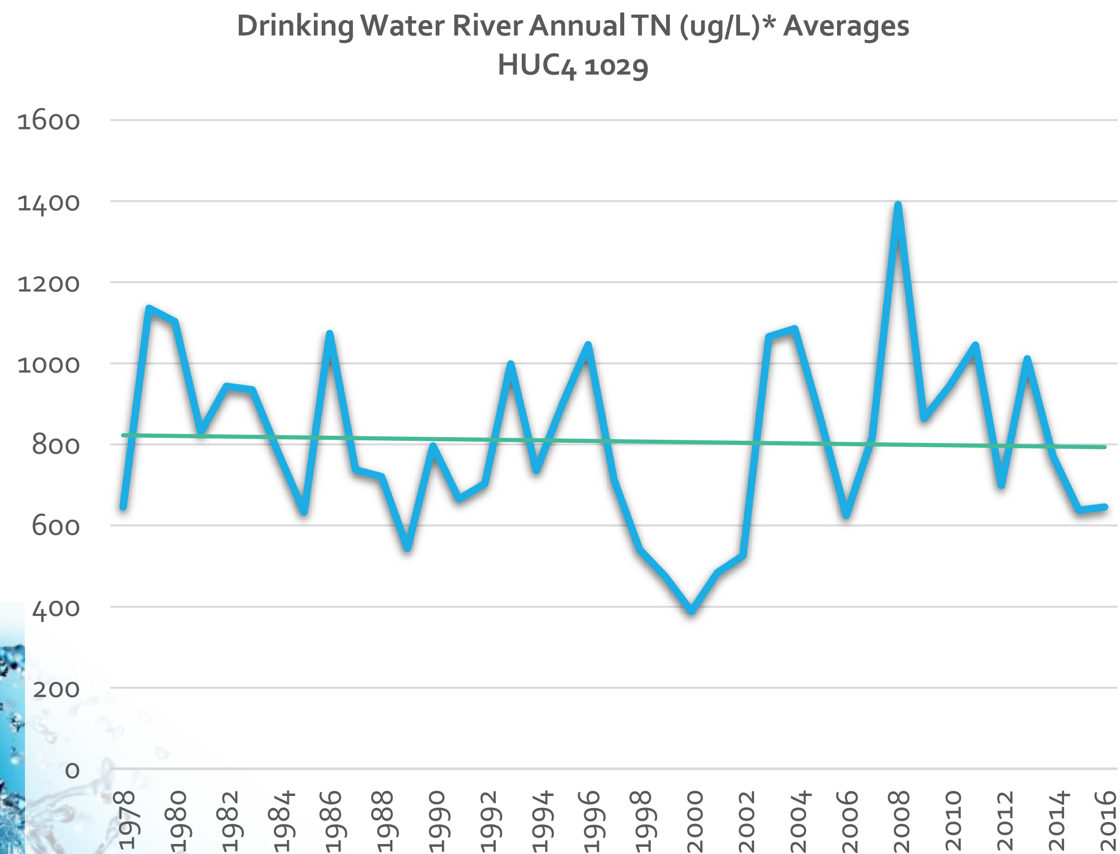
HUC 4 Basin	No. of Drinking Water Rivers
Upper Mississippi-Salt	11
Upper Mississippi-Kaskaskia-Meramec	6
Missouri-Nishnabotna	7
Chariton-Grand	13
Gasconade-Osage	5
Lower Missouri	3
Upper White	3
Neosho-Verdigris	1
Lower Mississippi-St. Francis	2

Drinking Water River Analysis
Gasconade-Osage Basin (HUC4 1029)



River Name	WBID
Marais des Cygnes River	1297
Pea Ridge Creek	1387
Gasconade River	1455
Big Piney River	1566 & 1578
Bates County Drainage Ditch	3832

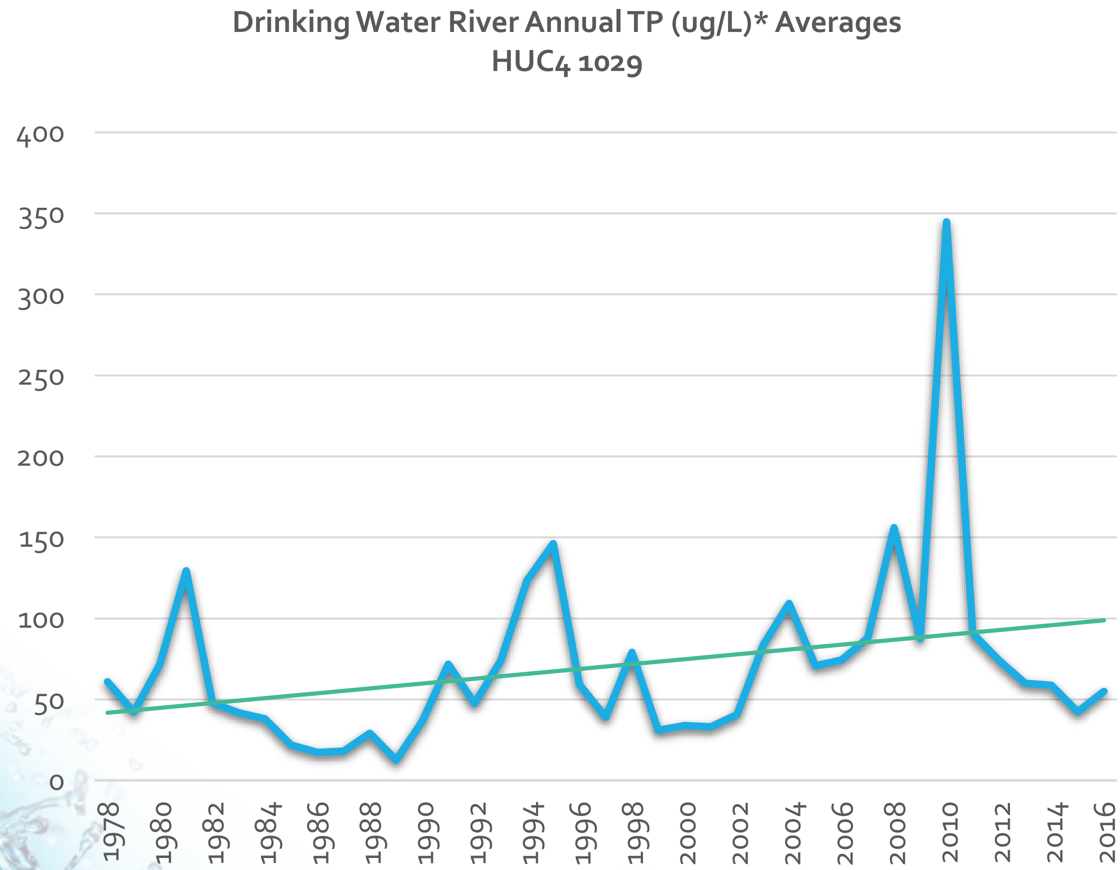
Drinking Water River Total Nitrogen Analysis Gasconade-Osage Basin (HUC4 1029)



*micrograms per liter

River Name	Number of Samples
Marais des Cygnes River	48
Pea Ridge Creek	41
Gasconade River	408
Big Piney River	169
Bates County Drainage Ditch	23

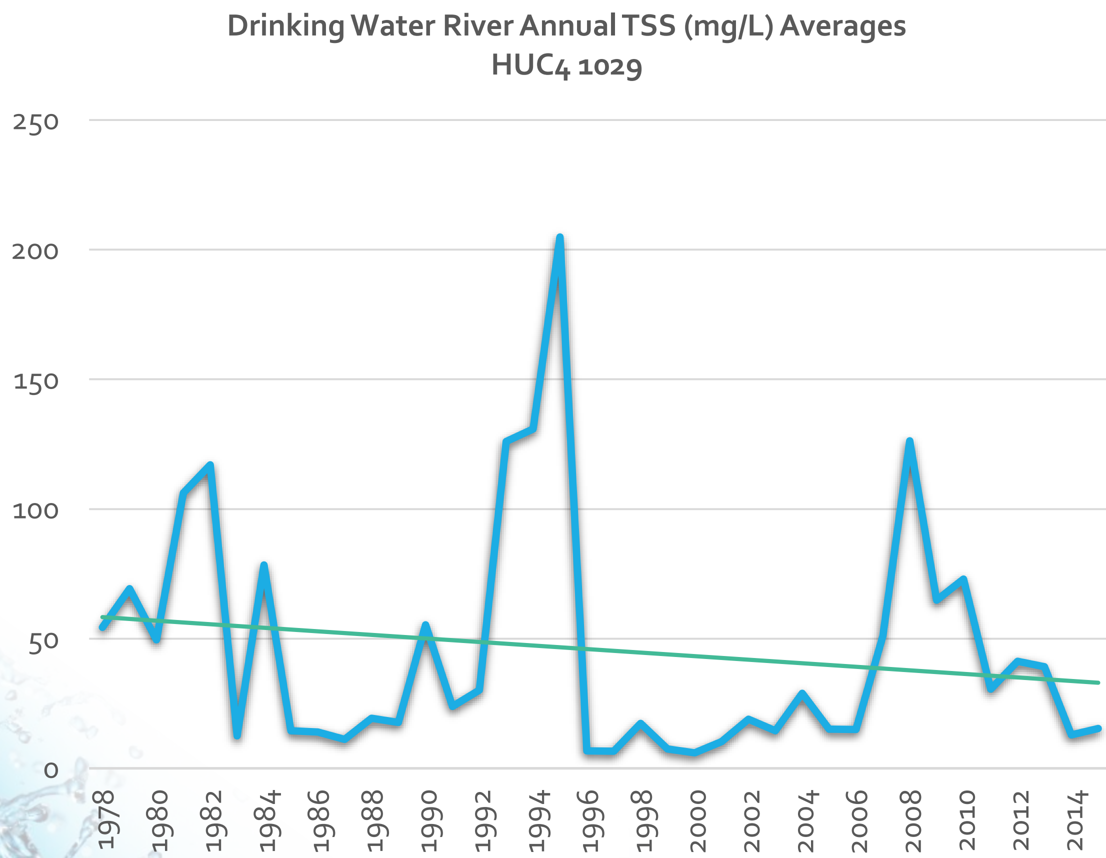
Drinking Water River Total Phosphorus Analysis Gasconade-Osage Basin (HUC4 1029)



*micrograms per liter

River Name	Number of Samples
Marais des Cygnes River	115
Pea Ridge Creek	41
Gasconade River	448
Big Piney River	255
Bates County Drainage Ditch	43

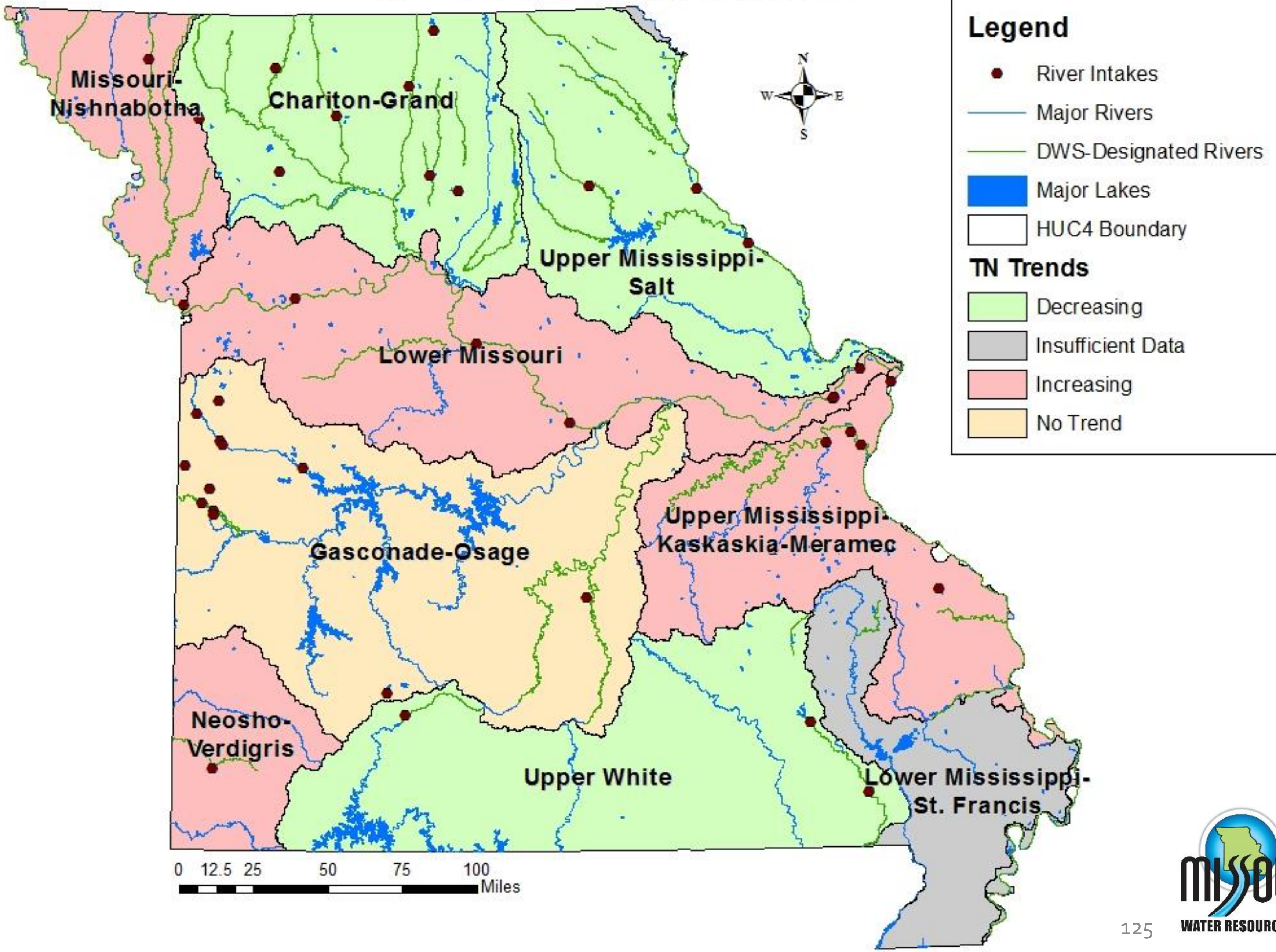
Drinking Water River Total Suspended Solid Analysis Gasconade-Osage Basin (HUC4 1029)



River Name	Number of Samples
Marais des Cygnes River	120
Pea Ridge Creek	41
Gasconade River	345
Big Piney River	224
Bates County Drainage Ditch	8

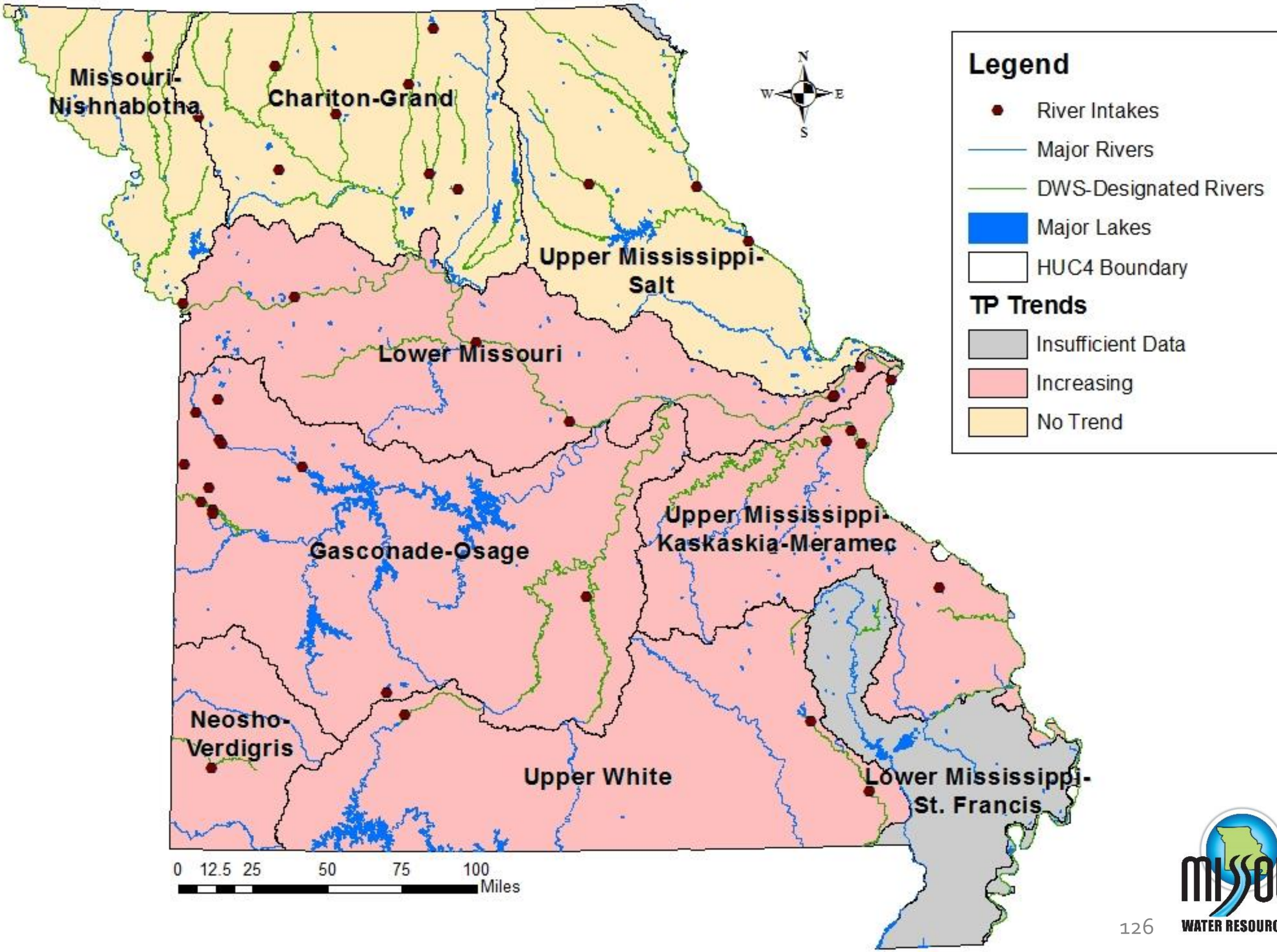
MISSOURI WATER RESOURCES PLAN

Annual Total Nitrogen Trends
HUC4 Basin Drinking Water Rivers



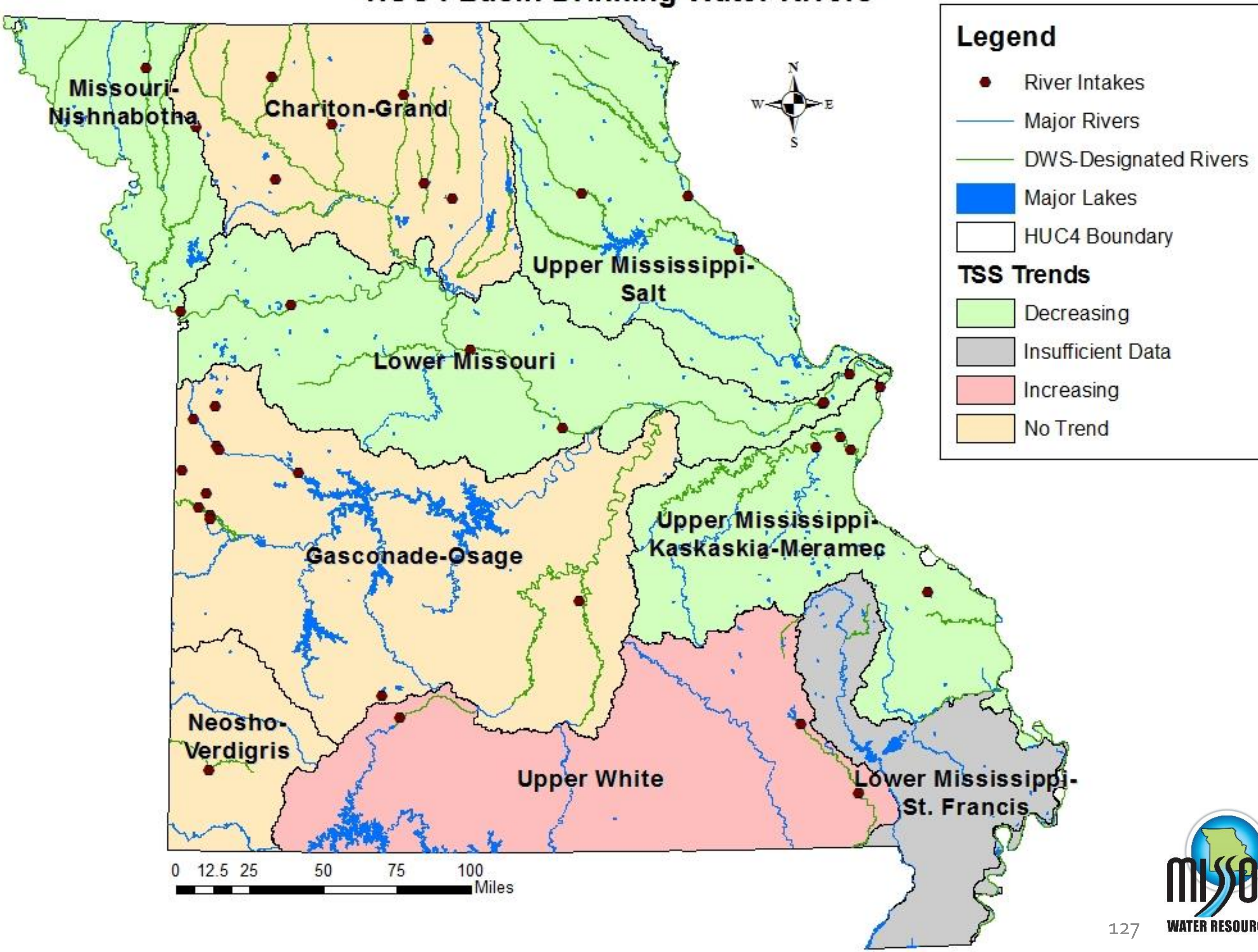
MISSOURI WATER RESOURCES PLAN

Annual Total Phosphorus Trends HUC4 Basin Drinking Water Rivers



MISSOURI WATER RESOURCES PLAN

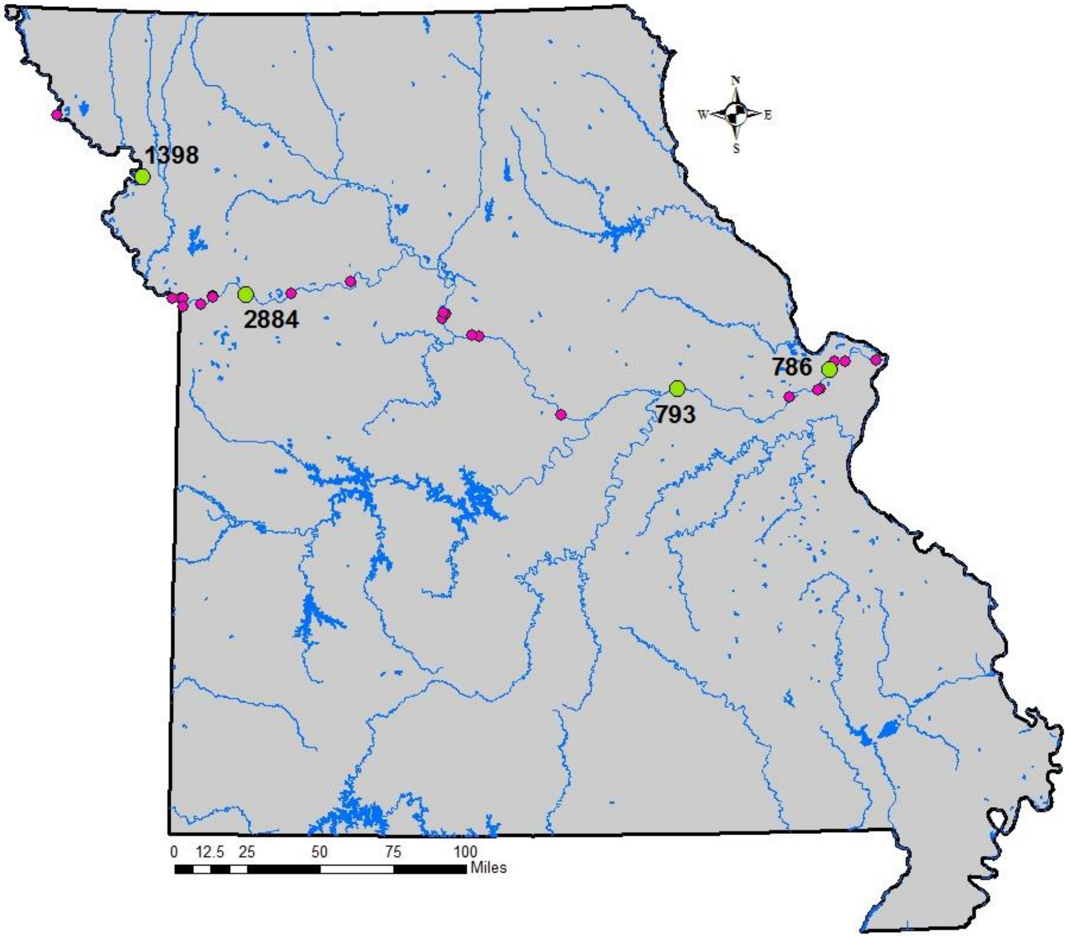
Annual Total Suspended Solid Trends HUC4 Basin Drinking Water Rivers



MISSOURI WATER RESOURCES PLAN

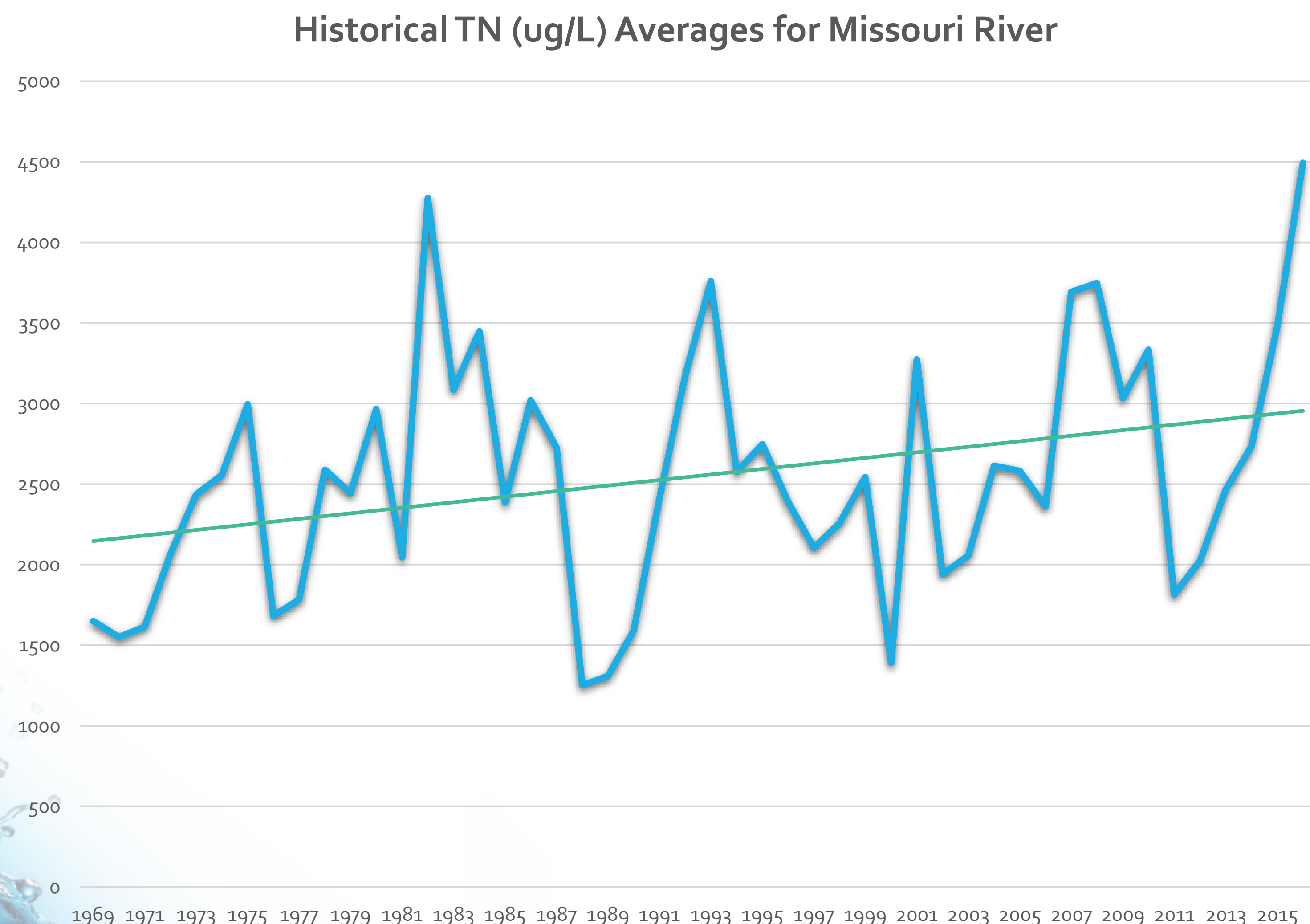
Missouri River Temporal Trend Analysis

- All monitoring stations on the Missouri River were reviewed
  - Sites with adequate historical data were selected for analysis



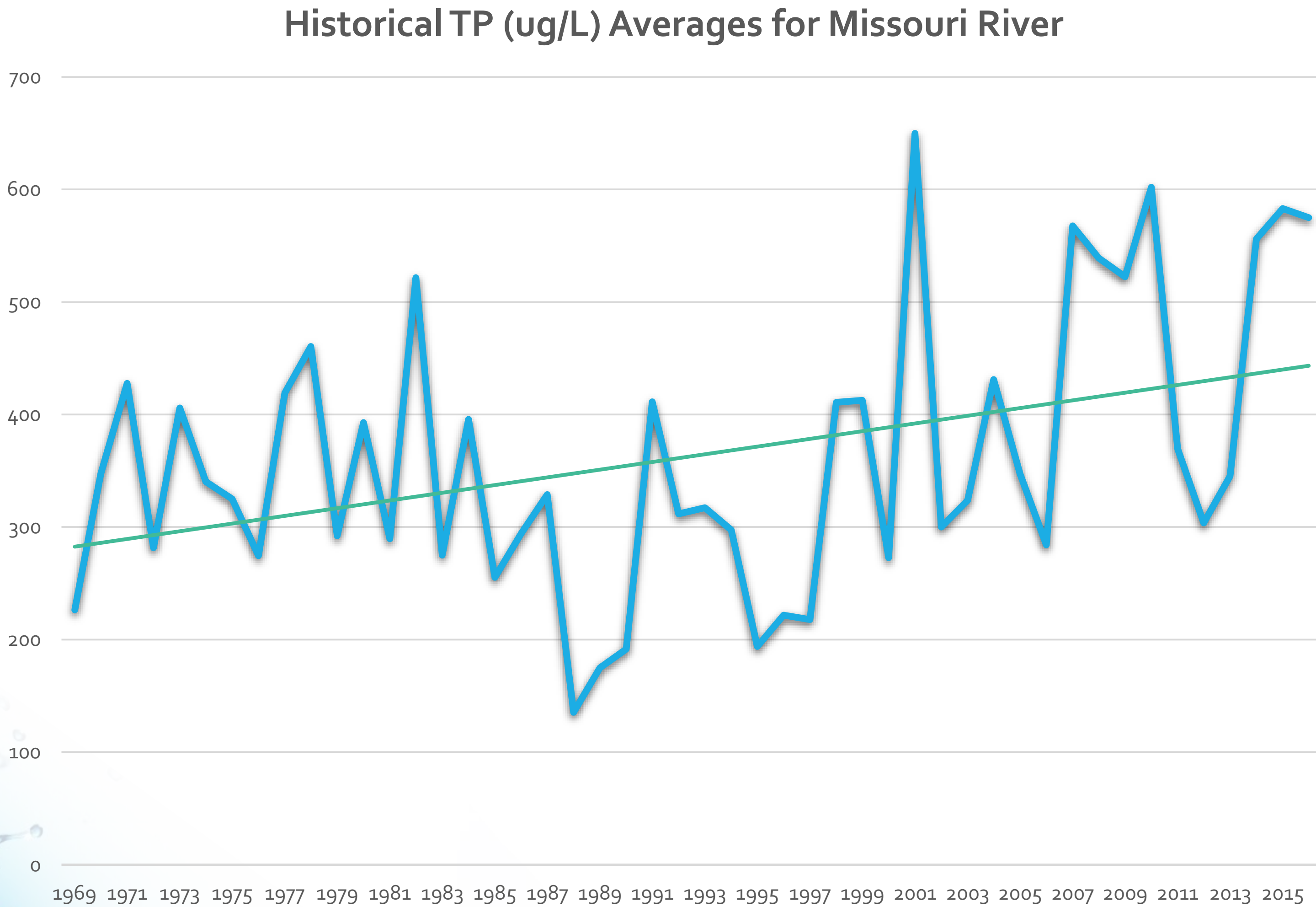
MISSOURI WATER RESOURCES PLAN

Missouri River Total Nitrogen (ug/L) Trends



MISSOURI WATER RESOURCES PLAN

Missouri River Total Phosphorus (ug/L) Trends



MISSOURI WATER RESOURCES PLAN

Bacteria and Recreational Uses

- Elevated bacteria levels in recreational waters pose a risk to human health

- MoDNR threshold value for beach closures is a 3-day *E.coli* geometric mean of 190 #/100 mL

- Areas with high recreational activity are regularly monitored for elevated bacteria levels
  - Lakes and Beaches
  - Primary Contact Rivers and Streams

MISSOURI WATER RESOURCES PLAN

Popular Water Recreation in Missouri

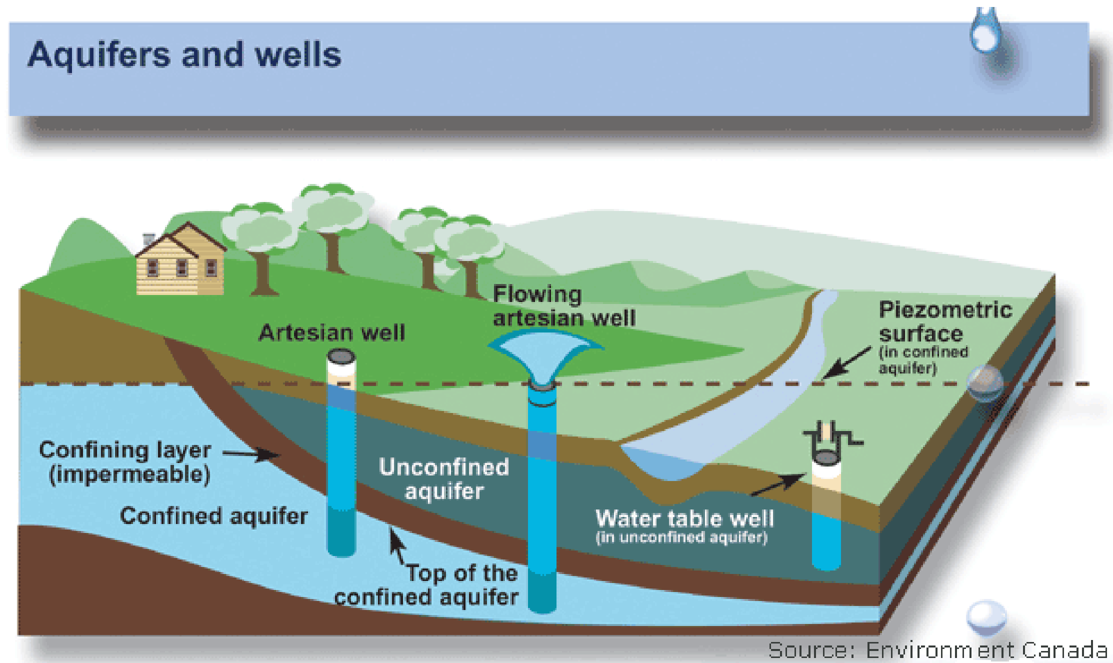
Recreational Water	N	Minimum *E. coli*	Maximum *E. coli*	Geomean *E. coli*	*E. coli* Trend
Lincoln Lake Beach (Cuivre River)	440	2	410	18.6	Increasing
Finger Lakes Beach	386	0.5[1]	461.1	9.1	Increasing
Long Branch Public Beach	409	0.5	396.8	4.5	Decreasing
LOTO[2] Public Beaches	946	0.5	980.4	18.9	Increasing
Mark Twain L. Beach	520	0.5	2419.6	28	Increasing
Moonshine Beach[3] (Table Rock Lake)	206	0.5	107.6	16	Increasing
Trail of Tears Public Beach (Lake Boutin)	406	0.5	185	11.3	Decreasing
Wappapello Public Beach	473	1	866.4	19.5	Increasing

1 *Values of 0.5 reflect non-detect concentrations.*
2 *Lake of the Ozarks.*
3 *Moonshine Beach E. coli data ranges from 2001–2012. Minimum, maximum, and geomeans are from 2012.*

MISSOURI WATER RESOURCES PLAN

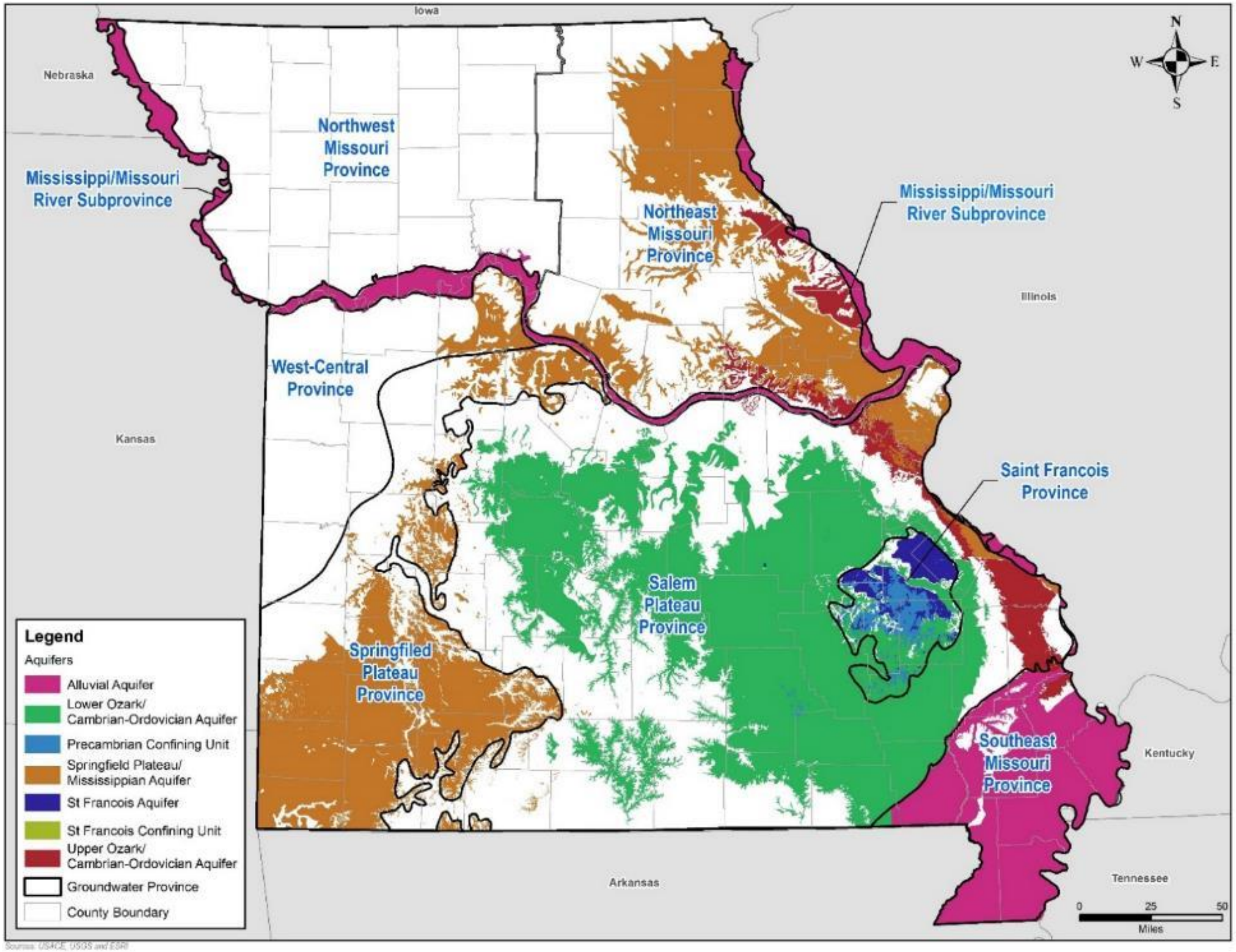
Groundwater Quality

- Statewide groundwater discussion
  - Uses
  - Monitoring
  - Issues/concerns
  - Water supply



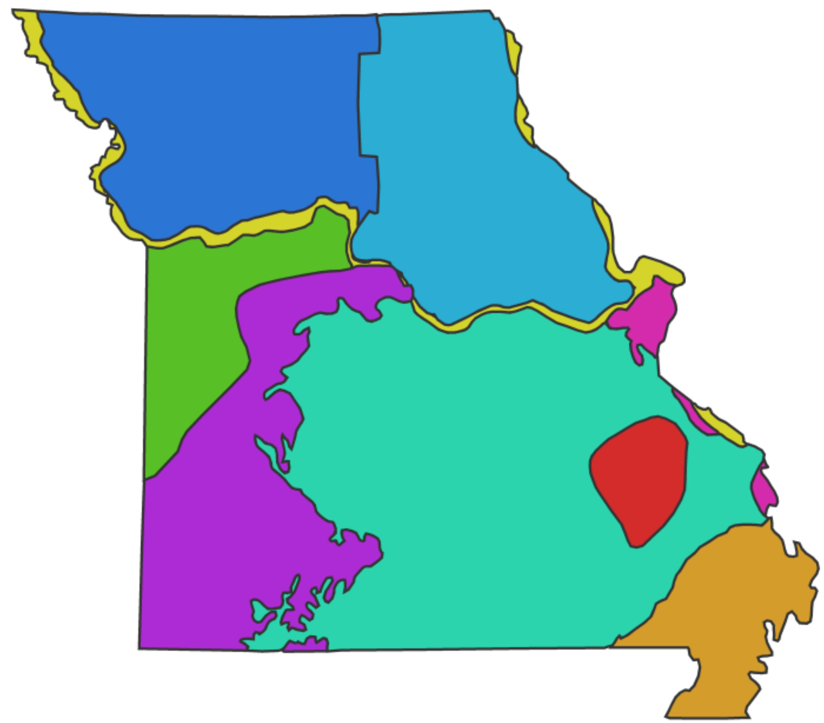
MISSOURI WATER RESOURCES PLAN

Major Groundwater Formations



Groundwater Quality

- Province-level discussion
  - Regional variation in groundwater uses and concerns
  - Data availability by region
- Temporal trends
  - Changes in groundwater use and quality over time
  - Emerging issues
  - Data limitations



https://dnr.mo.gov/geology/wrc/groundwater/

MISSOURI WATER RESOURCES PLAN

Emerging Issues

- What's on the regulatory horizon?
  - Nutrient criteria
  - Bacteria
  - Ammonia
  - Sulfate
  - Others
- Emerging contaminants
  - In both surface water and groundwater
  - Treatment implications
- Potential future impacts to water supply
  - Treatment costs
  - Infrastructure needs
  - Viability of residential drinking water wells

Next Steps

- Groundwater quality analysis
  - Site identification
  - Data limitations
  - Areas of concern
- Anticipated population growth/land use changes
- Integrating water quality assessment with water supply and demand analyses
  - Supply uses and future demands
  - Projections and trends
- Report development

Water Quality Discussion

IATF Report Out

- Spokesperson(s) attending the IATF Meeting
  - May 31, 2018 @ 9:00 a.m.
  - 10 minutes to talk
- Suggested Topics
  - Who is represented in the Technical Workgroup?
  - What are the key water resources needs?
  - What are the key challenges/issues/concerns?

Next Steps

Public Comments

Thank You